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October/November 1997
Volume 12, Number 4

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Special Graphic Supplement

To commemorate the U.S. Air Force's 50th anniversary, we've assembled a graphic pullout featuring a squadron of 50 prominent Air Force aircraft that span 50 years.

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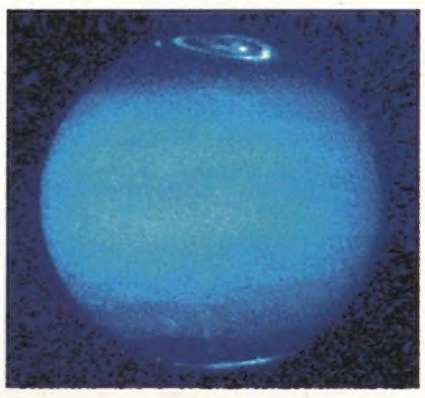

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Cover:
Two-tanker tango: A KC-10 refuels a KC-10 in this photograph by Chad Slattery.

Departments

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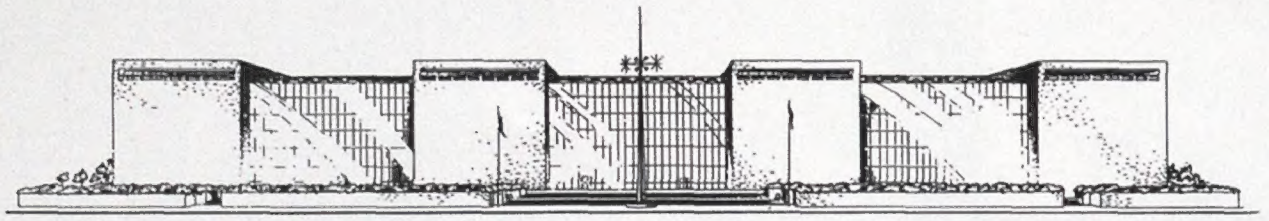

Inside 'Space Race'

The creation of major museum exhibits can be very complex undertakings. To collect artifacts and assemble them so they tell a story takes a good deal of thought and planning on the part of the museum's curators and the people who design the displays.

The artifacts are positioned both to provide visitors with the best possible opportunity for viewing and to tell a coherent story. The curatorial and design team creates concise, clear labels that are carefully placed, and throughout the development period the exhibit is reviewed repeatedly to ensure that it accomplishes its purpose effectively.

For the most part, we try to build an exhibit around artifacts in the collection, but we may not have everything we need to tell the whole story. Even the fabled National Air and Space Museum "attic"—our Paul E. Garber facility—may lack the full range of artifacts needed to give the necessary depth to an exhibit, and the planning team often must search elsewhere for what they need.

Not long ago, just such a challenge presented itself. We were looking for more artifacts for an upcoming exhibit that would compare spaceflight development in Russia and the United States. We were in this search mode in 1993 when the Museum staff learned that Sotheby's auction house in New York would be offering an extraordinary collection of Soviet space artifacts. When the auction took place, the staff watched eagerly to see who would acquire these treasures. But much of the collection went to a mysterious anonymous bidder.

To our surprise and delight, within days after the auction, the bidder approached the Museum to offer a loan of the artifacts. The events set in motion a cooperative effort that today is evident to all who visit the Museum's Space Hall. The new owner of many of the auctioned items was soon identified as a foundation created by Ross Perot, and the success of our exhibit, Space Race, as an unprecedented display of space artifacts is due to his civic-mindedness.

Space Race is about the progress toward lasting goodwill that came from the cold war, when two nations locked in a seemingly endless ideological competition were intense rivals in space. Now the two nations are cooperating in such projects as the international space station. The exhibit is multi-faceted, and by placing examples of Soviet and U.S. objects—satellites, spacesuits, spacecraft, and other artifacts—side by side, visitors can compare two approaches to achieving a similar goal.

The exhibit also tells the story of Corona, the super-secret U.S. project to photograph and monitor Soviet activity from space. The visitor can see a large satellite-borne camera and a gold-plated "bucket" that held canisters of film containing images of secret Soviet facilities. The film return capsules were ejected from the satellite; after they had reentered the atmosphere, they were snatched in midair by U.S. Air Force aircraft and their crews using innovative and complex recovery procedures. The story of this effort and the pictures that were the product of it are presented here publicly for the first time.

In another corner of Space Hall, tilted as if focused on some distant galaxy and dominant in its shimmering splendor, is the life-size engineering test model of the Hubble Space Telescope. The Hubble model was refurbished as part of the preparation for Space Race.

The daily showings of the IMAX film *Mission to Mir* in the adjacent Langley Theater augment the Space Race exhibit. This magnificent film catalogs life aboard the Mir space station, which has been in our headlines almost every day, and tells of the cooperative efforts of the United States and Russia to use Mir to expand our knowledge so that men and women can learn how to voyage beyond Earth.

I hope you'll come and see this amazing film and exhibit of an especially important part of the history of the cold war.

—Don Engen is director of the National Air and Space Museum.

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The bright spot in the day is 7:00 PM when, after the evening meal, families all across the nation gather around the radio to listen to their favorite programs. Imaginations provide the settings and the costumes. The villains are as menacing as minds can conceive. The leading lady is short or tall, blond or brunette. The leading man is as brave and gallant as the listener desires. The networks vie with each other to provide the funniest comedies and the most exciting dramas. Radio is *the* big form of entertainment for America's families, bringing the greatest and best-known stars into the living room night after night. This is The Golden Age Of Radio.

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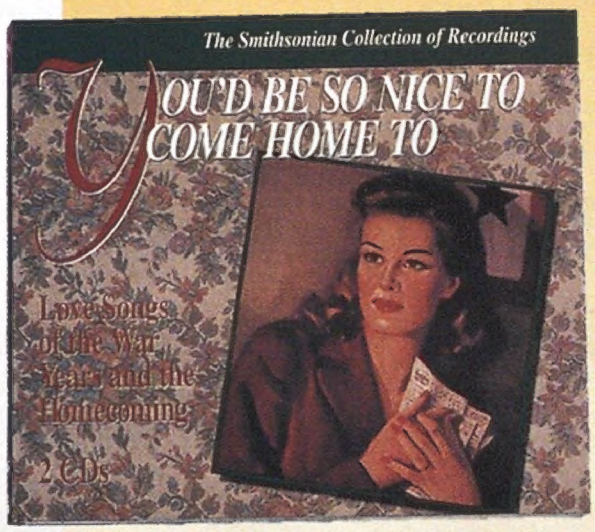

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LETTERS

What's So Special About John Glenn?

After being away from the space program for 35 years, what can John Glenn contribute to it by going on a space shuttle mission, as has been proposed ("Friendship 76," Soundings, Aug./Sept. 1997)? His seat should go to an up-and-coming scientist or astronaut who can contribute to space knowledge.

And please don't insult our intelligence by telling us that a trip by the 76-year-old Glenn would contribute data needed by the National Institute on Aging. If we send a senior citizen into space, it should be one who is bipartisan and who has the physique and the current space knowledge to perform age-related tasks in space.

—William E. Berresheim
Lake Zurich, Illinois

Whether John Glenn is sent into space will depend on politics. I, however, upon reaching age 60, will never fly as an airline captain again.

It isn't who you are or what you are, it's who you know.

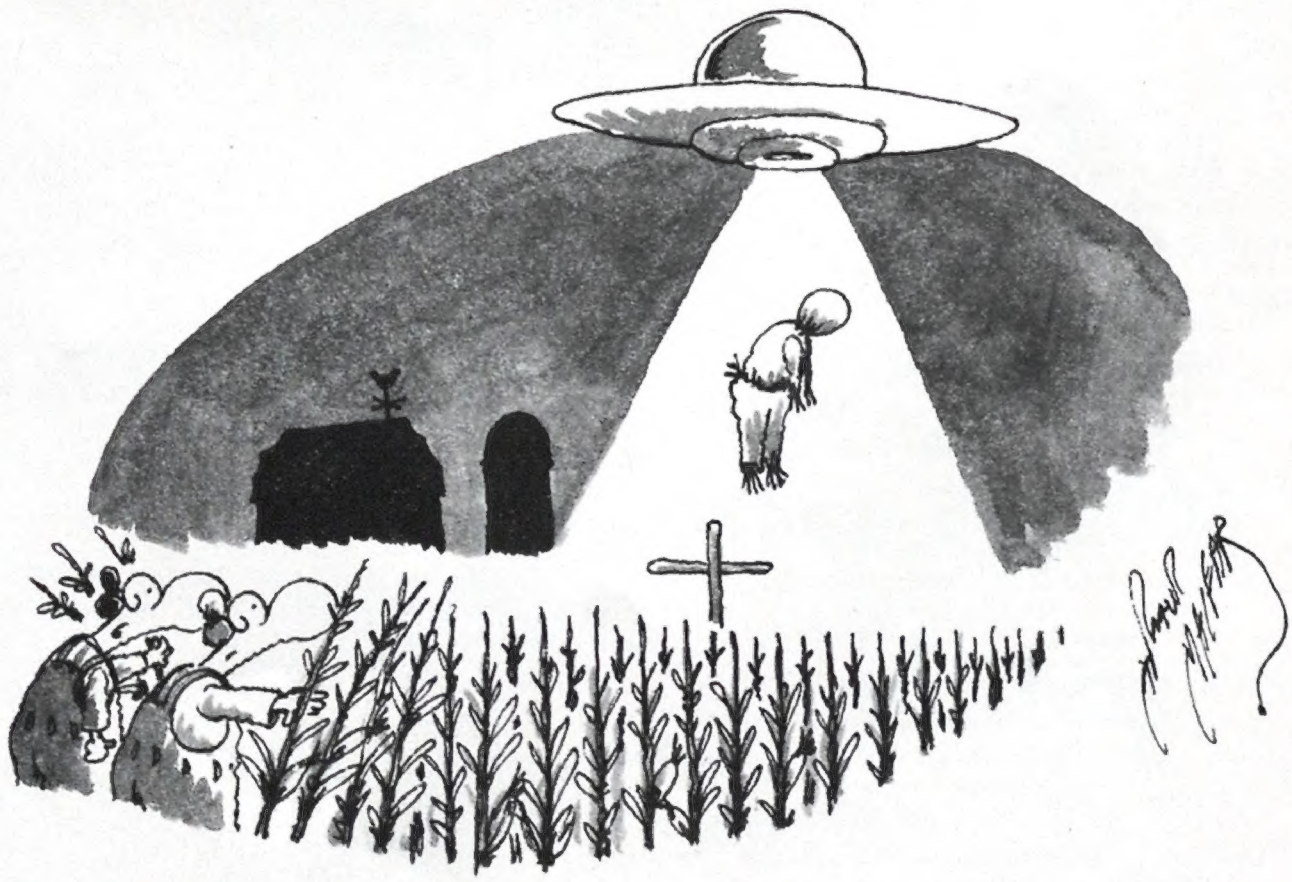
—Gary G. Gulbransen
Santa Barbara, California

Something Missing From the Reconstruction?

"The Reconstruction" (Aug./Sept. 1997) was great, but the vivid descriptions in the text cried out for detailed photographs of the reconstructed airplanes and the methods of laying out the parts. A picture of the "Jetosaurus Rex" frame before and after would have been interesting too. David Povilaitis' illustrations were too artsy, too chopped up (okay, I see the point there), and too washed out.

—Scott Coburn
Center Moriches, New York

In response to his article, I suggest William Triplett read the book *The Downing of TWA Flight 800*, in which James Sanders writes: "There can be no



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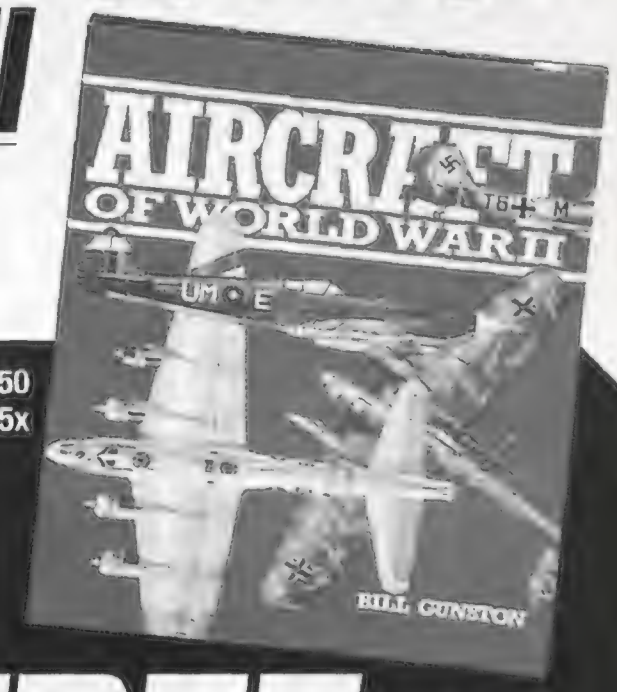

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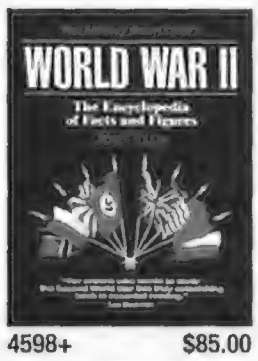

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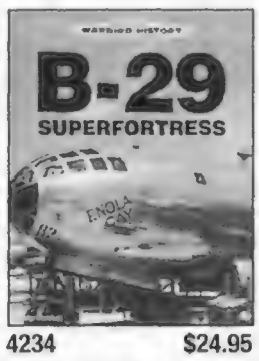

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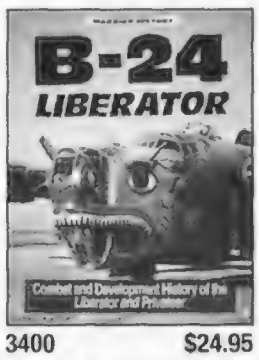

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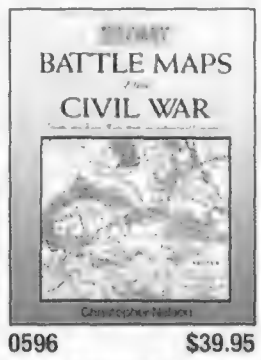

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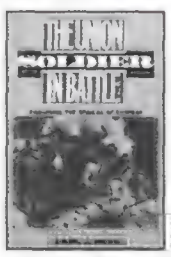

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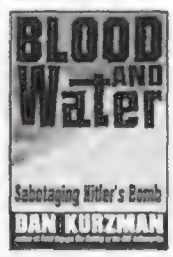

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other explanation: The U.S. Government knows that TWA Flight 800 was shot out of the sky by accident by an unarmed missile launched during a military exercise—but is attempting to hide this fact from the families of the victims and from the American people."

—Fred R. Breuninger
Muskegon, Michigan

Editors' note: For yet another theory on what caused the accident, see "Was It a Cosmic Catastrophe?," p. 16.

An Airtight Story

"The Making of Air Force One" (Aug./Sept. 1997) pointed out how far filmmakers will go to provide the public with supposedly realistic thrills. But when I saw the movie, I was amazed that the aircraft continues to fly, apparently without damage, even though a dozen men inside are having a shootout with automatic weapons. Where do all those high-velocity steel-jacketed slugs go? An M-16 is capable of driving a bullet through the cast iron engine block of a truck. Can you imagine what it would do to the light aluminum structures and electronics that aircraft are made of? When the military is ready to design its next fighter, it should hire Hollywood filmmakers.

—Steven E. Leary
Washington, D.C.

Ruing Those Raptures Over the Raptor

Contrary to the marketing hype that Carl Hoffman quoted in "The Raptor Cometh" (Soundings, June/July 1997), the F-22 is not the first aircraft capable of supersonic flight without afterburners. In 1954, the English Electric P.1, a concept demonstrator for the BAC Lightning, exceeded Mach 1 with dry power. The YF-23A demonstrated supercruise in 1990, and the F-15 Eagle can fly slightly supersonic on a lot less dry power than the F-22 has. All the Raptor can claim is that it is the first production aircraft capable of sustained supersonic flight without afterburners.

—Bob Dowgwillo
St. Louis, Missouri

More Ugly Remarks

I see from the correspondence in the last issue that my nominations for "Plug-Ugly" (June/July 1997) have struck a nerve,

particularly with the renowned P-61 fan club. I must point out to those who so eagerly hurled barbs at my delicate ego that the magazine's editors selected only three nominations from a much longer list I had submitted, at the top of which was the Fairey Gannet. (I confess, however, that I may since have changed my mind about the Gannet. I saw it fly at Oshkosh and it did not look half so bad as I remember.) My original list included several other Brits as well, so accusations of national bias are premature.

In any event, there is no accounting for taste. A mind that could believe that the sight, sound, and smell of a Lancaster, its four Merlins in full song, is not an aviation experience of surpassing glory and splendor must be disturbed indeed.

As for the P-61 enthusiasts, I am prepared to meet them behind the cowshed at dawn to defend my view.

—Air Vice Marshal Ron Dick
Royal Air Force (ret.)
Woodbridge, Virginia

American chauvinism again! It's bad enough for us southern hemisphere dwellers that Charles Lindbergh gets put on a pedestal while Charles Kingsford-Smith gets only a footnote. But to ignore the Transavia Airtruck T300 is beyond the pale. It is not only Australia's ugliest aeroplane, it is the world's ugliest. The fact that the crop duster usually smells of superphosphate only adds to its repellent qualifications.

—Rowan Partridge
via e-mail

Your description of the Ayres Loadmaster tore me up! I have never laughed so much over such an apt description of an aircraft—particularly since I had undergone a sigmoidoscopy the week before.

—Lt. Col. Martin O. Detlie
U.S. Air Force (ret.)
via e-mail

When I saw that you had an article entitled "Plug-Ugly," I wondered if the Shorts Skyvan would be included and was tickled to see that it was. Every time we taxied by one on the ramp, a crew member was sure to comment on the "Irish Concorde."

—Woody Woodward
via e-mail

Show Him the Money

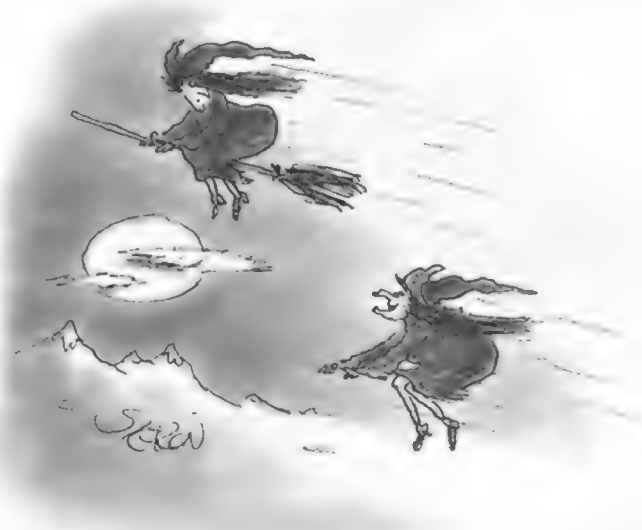
I was amused by the letter in the Apr./May 1997 issue suggesting that A-6 Intruders that are no longer needed be mounted in front of buildings as monuments. The writer's heart is in the right place, but his suggestion is idealistic.

The Navy donated an A-6 to Walker Field Airport in Grand Junction, Colorado. It sat at the airport for a little over a year before one of our local airport board members, a retired Marine A-6 pilot, took on the unenviable job of having the aircraft properly restored and mounted. Fortunately, he was able to draw on a variety of contacts and a sizable contingent of Vietnam veterans. From start to finish, the restoration of the airplane, including paint stripping and repainting, and the final mounting took a little over five months and required over $60,000 in labor and materials.

It is doubtful that every community, Elks lodge, and civic center could muster that kind of support and financing. In addition, each such group would have to maintain the aircraft and regularly submit paperwork to the Navy certifying that the aircraft was being kept in a presentable condition.

We don't need a monument to honor our veterans. We honor them in our hearts every day we walk the streets of America, knowing that because of them, we live in freedom.

—Dennis Wiss
U.S. Marine Corps (ret.)
Grand Junction, Colorado



Stealth broom!

In and Out Without a Trace

I've been a pilot in the helicopter logging industry here in the United States for 19 years. You'd need to change very little to make the article "Natural Selection" (Apr./May 1997) apply to the typical North American heli-logging operation. The sound environmental results, the difficulty, the bravado, the bad language—they're all the same.

The article states that "conventional heli-loggers often lift logs from cleared patches of land." I'd like to make it clear to your readers that in the United States, at least, heli-logging a clearcut area is very rare. We normally do select-cut logging: pulling out the extra growth and the dead and dying. In this decade, I've done only one clearcut.

I like to drive by a hillside we logged the year before. Nothing's torn up. You can't tell we've been there. That's what it's all about.

—Mac Miller
Eagle Point, Oregon

Big News in a Small Town

I remember the day my mother took me and some friends out of school to go see the *Hindenburg* zeppelin fly over the railroad station in Darien, Connecticut ("Company Town," Feb./Mar. 1997).

It is difficult to describe the sight of that great airship and the impression it created. Imagine an object the length of two and two-thirds football fields, and as big around as a 13-story building is tall, floating slowly and quietly overhead. It was low enough so that we could read the name on its side easily. Hitler's swastika stood out clearly too. The cinematic special effects people would have a difficult time creating such a dramatic sight today.

—George S. Robinson
Springdale, Arkansas

Naive Ideas About Innocents

I read "Loss of Innocents" (Commentary, June/July 1997) with dismay. On the surface, trying to do something to reduce the loss of innocent lives during wars sounds wonderful. However, William Forman's suggestion that the nations of the world formulate an international air war convention is completely without merit.

Today, it is impossible to separate the air war from the land war or the war at sea. In any conflict between major nations, all three elements (plus space) will be exploited. In a war between lesser nations, the combatants will fight with whatever they have. It is absurd to differentiate between killing noncombatants from the air and killing them in other ways.

It is equally absurd to arbitrarily pick one element of military power to constrain. If we are unsure of the nature of our targets, would Forman have us send more ground troops into enemy territory so that they can politely knock on each door and ask if any enemy troops are present?

To lessen the suffering of innocents, let's use our continued strength to lessen the possibility of war breaking out in the first place. And when we become embroiled in conflicts we can't avoid, let's win them as quickly as possible.

—Captain Richard E. Donnelly
U.S. Air Force
Navarre, Florida

William Forman argues that in formulating a new international air war convention, "we must go further" than the proposed Hague Convention of 1923. I do not see why the Convention's Article 22 of Rules of Aerial Warfare is objectionable for our time. The article prohibits "[a]erial bombardment for the purpose of terrorizing the civilian population, of destroying or damaging private property not of a military character, or of injuring non-combatants." Perhaps only practitioners of Total War and defenders of "collateral damage" would disagree with that prohibition.

Incidentally, the 1940 Luftwaffe attack on Rotterdam killed 870 civilians, not, as Forman stated, 30,000 to 40,000.

—G.A. Mahler
Danville, California

Who Gives a Hoot for the Hortens?

After reading your article on Jack Northrop's reinvention of the wheel ("The Edwards Diaries," June/July 1997), I had looked forward to reading the next issue's letters column, which I was sure would have a spectacular donnybrook about the German flying wings that had been designed by the Horten brothers. But curiously, the silence of the Horten supporters was deafening.

—Richard Heier
Lansing, Illinois

"Sorry, we couldn't do anything with your vintage engine, so we had to install a new one."

A Miserable Job

I take offense to Karen Gooding's letter in the June/July issue, in which she referred to the article "Chapel of the Thunder Gods" (Collections, Apr./May 1997) as "a load of crap."

In war, people on either side are forced to do things they would rather not do. I am sure that James Doolittle's Raiders, Claire Chennault's Flying Tigers, and the crew of the *Enola Gay* would rather have been at home than waging war. I am also sure that the young kamikaze pilots described in your article would rather have been with their family and friends than flying suicide missions.

When I see a Superfortress, a B-25, a Warhawk, a Zero, or an Ohka bomber, I am mostly taken with its beauty and power. A part of me is saddened that these aircraft were designed as lethal weapons and not the works of art they ultimately became. I am grateful that there are museums, such as the one described in your article, that display these machines and tell the story of the men and children who were tasked to make them work.

I enjoyed "Chapel of the the Thunder Gods"—and I have to say I'm glad those 50 Hellcats showed up when they did.

—Richard J. Kinney
Clovis, California

A Mere Shell of Its Former Self

In "Gary and the Pirates" (Feb./Mar. 1997), Carl Hoffman refers to Gary Larkins traveling to Carpenter Lake in Canada's Northwest Territories and salvaging an "intact" P-39 there. I know that airplane, and it was not intact.

In December 1943 Lieutenant Delos Carpenter had been flying the aircraft to Fairbanks, Alaska, when weather problems set in and he was forced to land gear-up at a lake (later named after him). The following January and February, I served as a UC-64 Norseman pilot who helped service an operation to salvage that P-39. We cannabilized the tail section, ailerons, engine, guns, radio, instruments, landing gear, servo motors, windscreen, canopy, door, and other parts. By the time we were finished, all that was left were the wings and the fuselage.

—Jess Hall
Weatherford, Texas

Why the "W"?

"The Lighter Side" (Collections, Dec. 1996/Jan. 1997) mentions

the Bellanca Aircruiser's W-shaped bottom wing. The "W" wasn't a wing so much as a lifting strut extending from the tip of the upper wing to the landing gear. It reflects G.M. Bellanca's conviction that every aircraft structure, including the fuselage, have an airfoil to help with lift and stability. Perhaps the Aircruiser should be called a sesquiplane—something between a monoplane and a biplane.

—Alan Mann
Wilmington, Delaware

The Pancho Barnes Story

For a biography of pioneering aviator Pancho Barnes, I would appreciate hearing from anyone with memories, anecdotes, correspondence, or other material related to her life.

—Lauren Kessler
84898 S.Williamette St.
Eugene, OR 97405
e-mail: ljk@oregon.uoregon.edu

Corrections

Aug./Sept. 1997 "The Making of Air Force One": The photograph at the bottom of p. 74 should have been credited "AP photo/Ken Cedeno."

June/July 1997 Sightings: The top right photograph was made by clamping a motor-driven Nikon camera with a 20-mm lens in front of the aircraft's wing and tripping a trigger taped to the pilot's control stick.

"It Keeps Going and Going and Going..." (Soundings): Eight watts is the power of Pioneer 10's radio transmitter, not its radioactive power source.

"Plug-Ugly": The XF-91's wings were variable incidence, not variable sweep.

Apr./May 1997 "Collision Course": In the 1962 all-jet Bendix race, a B-58 Hustler flew from Los Angeles to New York in two hours, 56 seconds, not two hours, 56 minutes.

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ARECIBO, STILL NUMERO UNO

DAVID PARKER/SCIENCE PHOTO LIBRARY

When Bill Gordon first hiked into the mountain hollow in central Puerto Rico that today cradles the giant Arecibo Radio Telescope, it was nothing but tobacco fields and a small leaf-drying shed surrounded by tropical forest. It was 1958, and Gordon, then a professor of electrical engineering at Cornell University, had come up with a clever idea. His sponsor, the Pentagon's Advanced Research Projects Agency (ARPA), wanted a radio antenna—a *really big* antenna—to study the thin upper atmosphere through which ballistic missiles would travel. But the 1,000-foot dish ARPA required would likely collapse under its own weight. Why not use the Earth itself for structural support, Gordon thought.

After searching through textbooks on karst topography—natural limestone depressions found throughout the world—and considering sites in Cuba ("Thank God we didn't do that in 1958") and elsewhere, Gordon and his colleagues settled on this particular bowl-shaped valley in Puerto Rico. Five years later, with funding from the Air Force, the Arecibo radio telescope opened for business.

Last June, Gordon was among the 300 scientists, dignitaries, and guests on hand to inaugurate the newly upgraded telescope and pay homage to what is still the world's largest single-dish radio antenna. National Science Foundation director Neal Lane called Arecibo "one of the most beautiful instruments, scientifically and aesthetically, ever built." Frank Drake, who pioneered the Search for Extraterrestrial Intelligence (SETI), couldn't attend but sent a congratulatory message lauding the antenna as "one of the modern wonders of the world."

A catwalk 450 feet above the dish leads to the telescope feeds, where radio waves striking the 18-acre dish come to a focus. The feeds were much improved in the course of this $27 million upgrade, which is Arecibo's second makeover since the NSF took over the observatory in 1970. Back when Gordon was conducting atmospheric studies for the Air Force, he says, "astronomy was a fringe benefit." Now it's the primary purpose.

The telescope's tremendous collecting area makes it sensitive to the faintest whispers from remote radio galaxies, but sensitivity comes at a price. Because the massive dish is anchored in its crater, it can't be steered like other radio telescopes. A conventional parabola-shaped dish would have doomed it to viewing only the sky directly overhead. So Arecibo was built with a spherical dish, which catches radio waves from all directions. The feeds, rather than the dish, are then moved to the optimal position. The bad news is that the focus of such an instrument is sloppy.

Because blurring is not that big a problem for long-wavelength radio observations, astronomers were not inclined to complain. "Forty years ago, I was just happy to get the dish!" says

Gordon. But now the old feed system has been replaced with an ingenious new one. Perched above the main dish and facing downward like a beanie cap is a smaller secondary dish that refocuses the energy to a third, upward-facing reflector, which focuses it yet again, even more tightly. The result of this and other improvements is that the upgraded telescope, once it goes fully operational this winter, will be about 20 times more sensitive for viewing solar system objects and three or four times better for galactic astronomy.

Asteroid observers will be among the many beneficiaries, since NASA also paid for a more powerful transmitter that bounces radio energy off solid objects so scientists can listen for the faint echoes. Arecibo has already been used in this way to study the surface of Venus and the moon. Now it will help to map small asteroids whose orbits cross that of Earth. Astronomers who have been able to study only a handful of these objects after decades of trying will now get radar images of several Earth-crossers every year, with resolutions down to 32 feet.

Arecibo also will continue as the premier instrument for SETI. Jill Tarter of the SETI Institute in Mountain View, California, plans to be back on the big dish next summer, with an automated hunt for radio signals that suggest intelligent origin. One famous Arecibo experiment that's unlikely to be repeated, though, is a 1974 message *out*. The digital signal, beamed in the direction of the globular cluster M13, included information about us humans, our genetic makeup, and our solar system.

Now, says Tarter, "society has changed," and that kind of attention-getting maneuver is no longer in the cards. We're more circumspect and safety-conscious than we were in 1974, and less confident that the universe is a friendly place. Who knows who might hear us? Better keep our voices down.

—Tony Reichhardt

UPDATE

Beefing Up the Border Patrol

The United States Border Patrol in San Diego, California, is replacing its Hughes OH-6A helicopters with as many as 45 Boeing MD-600N single-turbine Notar (no tail rotor) helicopters ("Holding the Line," Dec. 1988/Jan. 1989). The eight-place helicopters will join the Super Cubs and Christen Huskies that the patrol uses to monitor the U.S. southern border for illegal entries.

COURTESY DENTPRO

Leader of the Pack

Jim Neilson is to aviation what Martha Stewart is to entertaining: Both are artists with a knack for transforming discards into something extraordinary.

Neilson's detritus is a Westinghouse J34, a monster engine that thundered over the earth during the Jurassic era of the Jet Age. A gluttonous turbojet with an 11-stage axial-flow compressor and two-stage turbine, the J34 saw duty during the Korean war in the McDonnell F2H Banshee and Douglas F3D Skyknight.

A former motorcycle racer, stunt man, commercial fisherman, and funny-car driver, Neilson was looking for something to put him ahead of the crowd of raceway showoffs. In 1986 he came across a salvageable J34 for peanuts and he knew he had found his way to the front of the line—way out front.

Neilson mounted the engine on rails and the rails on wheels. The awesome result was a jet-powered dragster. But in the two years the racer was under construction, similar machines hit the track, powered by a variety of aviation turbines, including the General Electric J85 and Pratt & Whitney J60. Nielson needed to turn up the wick.

To get more go, he designed and hung an afterburner on the tail end. Next, he rented a Mercedes 500SEC limousine and slathered it with goo to create body molds. He built a fiberglass knockoff narrowed by almost a foot, lengthened by four, and lowered to ant-high clearance. He installed a roll cage, added drag chutes, and sprayed on white paint, and the world's first Jet Limo was born.

The car rolled onto the pavement in late 1992 and has been setting records ever since. As with airplanes, the key to its performance is its power-to-weight ratio. The Jet Limo weighs 2,300 pounds, of which 1,300 is Westinghouse. When new, the engine pumped out over 3,000 pounds of thrust, a figure Neilson says he's cranked to more than 7,000.

A typical performance involves the car being towed onto the roadway (there's no transmission or drive train), where a trio of 8D Caterpillar batteries jolts the J34 to life. Once the umbilical cord is disconnected, Neilson, feet planted on the brakes, advances the throttle to low rpm and a 50-foot flame erupts from the tail (sometimes he incinerates a car as part of the act). As he increases power, the engine emits a series of ear-splitting explosions until at 104 percent, the 30-foot limo begins to roll. "It'll go 260 in a quarter-mile with the brakes on," he says, adding, "Of course, you'll have square tires."

When the afterburner kicks in, Neilson says he's slammed back into the seat with a force of six Gs and the speedometer spikes past 100 in about a second. Top speed is 380 mph, but the 400 mph mark should fall soon. Speed makes a mockery of efficiency: The limo consumes 30 gallons of fuel in its quarter-mile, five-second jaunt.

The mad spectacle has proved so popular that Neilson is building a second Jet Limo, an ersatz Lamborghini Countach, and may even build a third. He's got enough engines. But would he ever consider taking one aloft? A long-inactive pilot, Neilson shudders at the idea. "Little airplanes are not very safe," he says. "I don't feel comfortable in them. You can be out of control real fast."

—William Garvey

A Twice-in-a-Lifetime Experience

"It's great to be back on Mars" is a line only characters in science fiction stories get to say. But I was thinking that, or something like it, when NASA's Mars Pathfinder spacecraft arrived at the Red Planet last Fourth of July. Twenty-one summers earlier I had worked as a college intern at the Jet Propulsion Laboratory in California on the first Mars landing, Viking 1. When Pathfinder made its "bump-down" on the Martian surface, I was back at JPL, this time as a journalist.

Even as I awaited Pathfinder's landing, Viking was never far from my thoughts. I could still vividly remember seeing Viking 1's first picture from the surface of Mars on July 20, 1976. It was just a footpad and some rocks—but nothing could have been more exciting. That day, I knew the thrill of seeing things no one had ever seen before; now I was about to feel it again. So were many old friends who had come to JPL for the event, including Gerald Soffen, who had been Viking's project scientist. In the minutes before Pathfinder's touchdown, Soffen said quietly, "I've been waiting for this moment for 21 years."

When the moment came, it was worth the wait. Pathfinder's pictures were spectacular, and even a little familiar: They reminded me of the Viking landing sites. There were also things we hadn't seen before, including the pair of majestic hills nicknamed Twin Peaks. Best of all, Pathfinder's little rover Sojourner gave us Earthbound explorers a chance to move around on the surface of another world. Over the next few days, witnessing Sojourner's wanderings—which captured the imagination of hundreds of millions of people—I felt incredibly lucky: Pathfinder had given me a chance to have a once-in-a-lifetime experience twice.

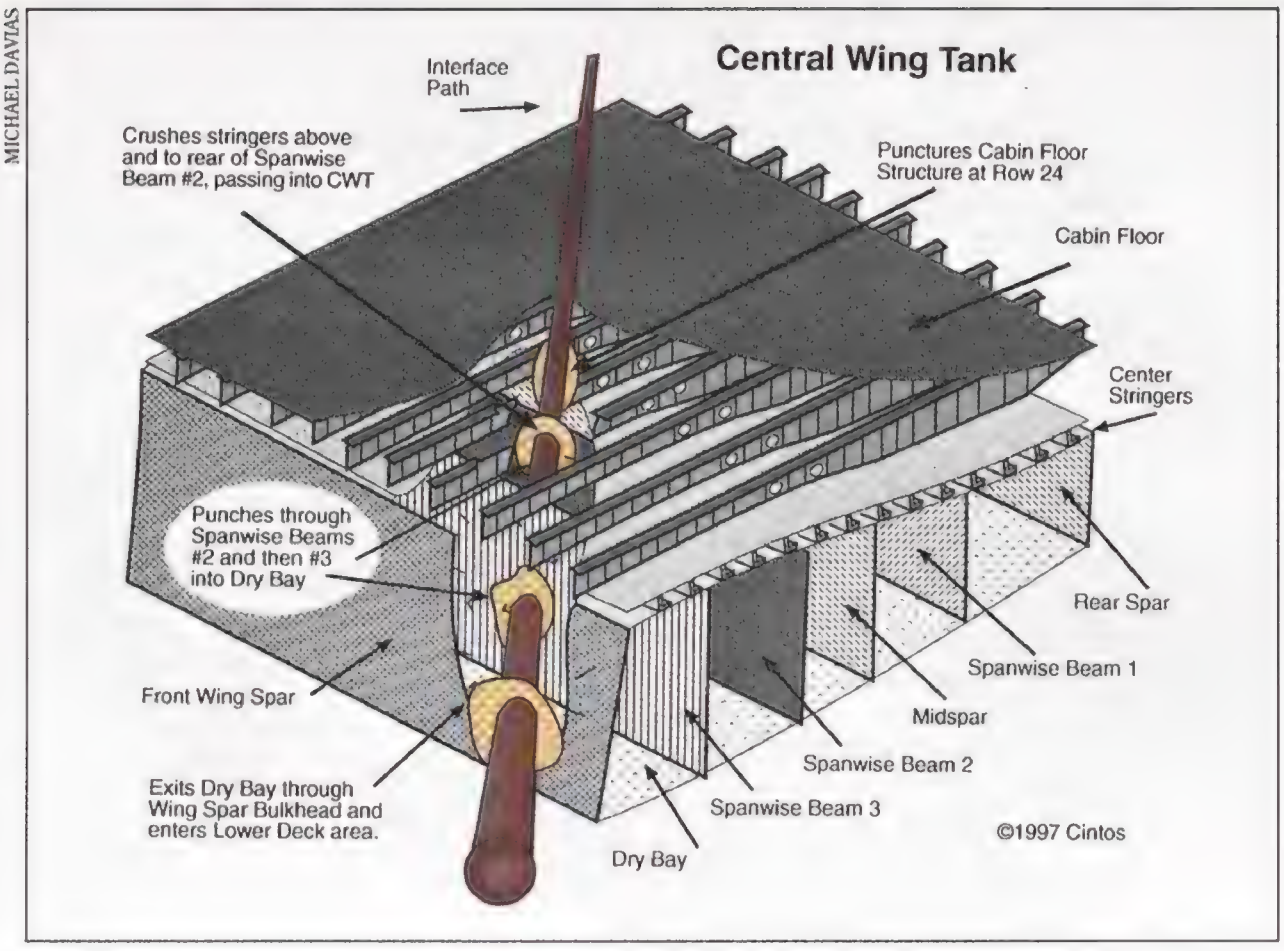
When I left JPL, images of Sojourner lingered in my head, and I was thinking that it would be a long time before human beings followed Pathfinder to Mars. But I really didn't mind—in that moment, I felt content. In fact, I felt as if I were already there.

—Andrew Chaikin

Was It a Cosmic Catastrophe?

More than a year after the July 17 explosion and crash of TWA Flight 800 off Long Island, investigators are still trying to determine the cause. The Federal Bureau of Investigation has withdrawn from the case, citing no evidence of criminal involvement, and investigators from the National Transportation Safety Board are still combing through the wreckage (see "The Reconstruction," Aug./Sept. 1997). Because of the nagging suspicion that this explosion was not "typical," theories abound, and one is particularly intriguing: that a space object called a bolide exploded near the 747, setting off the tragic chain of events.

MICHAEL DAVIAS



A bolide is a large meteoroid, explosively torn apart as it falls through Earth's atmosphere. According to Michael Davias, an amateur geologist and proponent of the bolide theory, the mysterious "streak" seen by eyewitnesses moments prior to the crash would fit with the entry and explosion of a bolide.

From there, at least one of the resulting pieces of the exploding meteoroid could have penetrated the fuselage and ripped through the almost empty central wing tank, destroying the aircraft's structural integrity and exiting the other side. "The damage to the CWT seems to start at the center and work its way forward along a discernible path," says Davias. "A fuel explosion would radiate damage in all directions." The vapor in the fuel tank could have ignited due to the searing heat produced by the bolide's high velocity, sealing TWA 800's fate.

There are other data that appear to fit the bolide mold: The sequence of multiple sonic booms heard by numerous witnesses onshore could be explained by the explosion and subsequent scattering of the heavier bolide remnants. In addition, the "estimated 200 holes" in the fuselage the FBI cited appear to be indicative of metal cut by objects traveling at extremely high velocity.

Most scientists shun the bolide theory, pointing out that statistically, such a strike is highly improbable (though not impossible). However, two scientists from Columbia University's astronomy department estimated in September 1996 that the chance of a meteor damaging a commercial aircraft is about 10 percent.

The National Transportation Safety Board is leasing a 747 for tests and collecting data on a recently exploded empty 747, their inquiries centering on the explosion of the CWT. But even with 95 percent of the aircraft recovered, the reason for the disaster may never be known. The small and final piece of the puzzle—whether it be a failed piece of equipment or a small collection of meteorites from a bolide explosion—may still lie on the ocean floor.

—Patricia Barnes-Svarney

UPDATE

Astronomical Loss

Fire and the water that quelled it have destroyed some 5,000 books—nearly half collected in the 1800s—at the library of Russia's Pulkovo Observatory last February ("Sunset on Pulkovo," Dec. 1994/Jan. 1995). Director Viktor Abalakin, who says there have been three attempts to set fire to the library, suspects organized crime. Abalakin says Pulkovo's astronomically hallowed grounds, near St. Petersburg, are eyed as a prime site for hotel construction.

UPDATE

LAURIE BECK CARVER

One Down, One Up

The Lockheed Super G Constellation that sat atop a restaurant-lounge in Penndel, Pennsylvania, for 30 years was plucked off with a crane, dismantled, and put into storage until a new home, preferably a museum, is found ("Offbeat Landings," June/July 1991).

Amoco, which bought the lot, is building a gas station and convenience store in place of the Airplane Diner, which closed in 1995. Because the new building is structurally unable to accommodate the Constellation, the oil company will top the station off with a six-foot replica of the airliner so locals can give the same directions they have been using since 1967 ("take a right at the plane").

In other Connie news, the Constellation Group has won Federal Aviation Administration approval to carry passengers on its airliner, in which the group also offers $4,000 flight training sessions ("Dreams for Sale," Dec. 1994/Jan. 1995). You can take a half-hour ride as a passenger for $300, half of which makes you a Constellation Group member.

Mir Lands in Wisconsin

A command and control module for the Russian space station Mir has come to rest in Wisconsin, a feat achieved not by gravity but the power of the dollar.

In Russia today, it seems, virtually everything is for sale, and last spring entrepreneurs there sold a backup core module for Mir to Tommy Bartlett's Robot World & Exploratory, a tourist attraction in Wisconsin Dells.

The module is one of three produced by the Soviets. The best known is in orbit, a second is in a Russian warehouse, and the third had been in a Moscow museum before Thomas Diehl, co-owner of Tommy Bartlett Inc., got his hands on it.

The hulking 20-ton module, complete with a spacesuit-clad mannequin hovering above, is tilted at a 30-degree angle, giving visitors an unsettled if not weightless feeling. Inside, a cosmo-dummy peddles an exercycle overhead. Another sits mesmerized at a control panel in the forward compartment.

A hole cut through the bulkhead allows easier entry and exit than was provided Norman Thagard, the first American to live in Mir. The recently retired astronaut, who spent 115 days aboard the space station, was on hand last April to kick off the new exhibit, pointing out where he ate, worked, and slept (a zippered sleeping bag on the module wall).

Just as it did for Thagard, the module represents a new level of achievement for Diehl. Sixteen years ago, when he was named president of the company, Tommy Bartlett Inc. was known only for its water-ski show. "The purpose of Robot World was to provide an all-weather attraction that would take the peaks and valleys out of our cash flow," he says. The Mir module will help. But the price was high: Purchasing, shipping, and assembly cost about a million dollars.

With the module and cosmonaut mannequins came other exhibit pieces. Alongside the module is a mockup of Sputnik I, the world's first artificial satellite. Also on display is some equipment that will never be used the way they were in Russia: a gyro capable of spinning riders into motion sickness and an old MiG cockpit with an ejection seat that boosts the occupant about two feet before stopping abruptly. "The liability laws in this state are just a hair too strict to operate them," Diehl says. "I can just see the whiplash cases coming in."

—Greg Freiherr

IN MEMORIAM

CAROLINE SHEEN

KATHERINE LAMBERT

The fields of aviation and astronomy lost two of their brightest stars last July.

Aerobatic superstar **Leo Loudenslager** *(left)*, seven-time U.S. National Aerobatic Champion and 1980 World Champion, died July 28 from complications of injuries he received when a Tennessee motorist crossed the centerline and hit Loudenslager's motorcycle head-on a month earlier.

Loudenslager, 53, was long considered one of the world's finest aerobatic pilots. He was about to debut an airplane he had designed and built over the last 10 years. Loudenslager was also a senior captain with American Airlines, an officer of the International Council of Airshows, and an inspiration to pilots everywhere. He is survived by two daughters, who request that any memorial donations be made to the Leo Loudenslager Aviation Memorial Fund, Franklin National Bank, P.O. Box 625, Franklin, TN 37065.

Eugene Shoemaker, who founded the U.S. Geological Survey's Center for Astrogeology, proved that Arizona's huge crater was created by an asteroid impact, and with wife Carolyn discovered some 20 comets and 800 asteroids, died July 18 from injuries incurred in a head-on collision in Australia's outback.

Shoemaker, who was 69, was best known to laymen for his co-discovery of comet Shoemaker-Levy 9, which made a spectacular assault on Jupiter in 1994. His original goal, to be the first scientist on the moon (Soundings, Feb./Mar. 1994, "Apollo's Geology Lesson, June/July 1994), was thwarted by Addison's disease. At the time of his death he was serving as an astronomer at Lowell Observatory in Arizona with his wife.

The Force Is Still With Us

"You don't know the power of the Dark Side!" intones Darth Vader. Oh, but indeed we do.

Vader, all seven black-armor-clad feet of him, is one of cinema's most entertaining villains—and a huge part of the appeal of the Star Wars trilogy created by George Lucas. The first film, *Star Wars: A New Hope*, was a hit when it was released in 1977, and the sequels, *The Empire Strikes Back* (1980) and *Return of the Jedi* (1983), were much awaited by Lucas' legion of fans. The films' pioneering special effects depicting space battles were widely hailed and widely imitated. But at its heart, the Star Wars trilogy is really just a good old-fashioned fairy tale, complete with a beautiful princess, an evil emperor, and a young hero named Luke Skywalker.

On October 31, "Star Wars: The Magic of Myth," an exhibit of more than 200 original props, models, costumes, and artworks used in the filming of the trilogy, opens at the National Air and Space Museum. Sponsored by Bantam Books, the year-long exhibit illustrates elements of classical mythology found in the trilogy's story structure and characters (including the ruthless Vader). Some of the artifacts on display include production models for the *Millennium Falcon* spaceship and an imperial star destroyer, props such as Luke's lightsaber and Han Solo's figure encased in carbonite, and Princess Leia's revealing slave girl costume (bravely worn by actress Carrie Fisher).

Mary Henderson, the exhibit's curator,

The artifacts in the "Star Wars: The Magic of Myth" exhibit include models and costumes for such characters as (clockwise from top left) Yoda, R2-D2, an Imperial guard, an Imperial probe, Luke Skywalker, Darth Vader, and Princess Leia.

got the idea to do something on Star Wars more than 10 years ago when her daughter was home sick one day. Henderson rented videos of the entire trilogy, and, while watching them with her daughter, she noticed that the three films, in narrating Luke Skywalker's transformation from a somewhat helpless young man into a powerful Jedi knight who saves the day, had the structure of the classic mythic hero's journey. Henderson, who interviewed Lucas during the course of her research, found out that the filmmaker's scripts had indeed been shaped by his study of different cultures and mythology. Says the curator: "Looking at it as a cultural artifact, I see that Star Wars really has become a myth for the 20th century."

—Diane Tedeschi

Admission to "Star Wars: The Magic of Myth" is free. Each day the Museum will distribute same-day passes (limit six per person) on a first-come, first-served basis. Tickets may be obtained in advance for a service charge of $2.25 each by calling (800) 529-2440. For more information, call (202) 786-2122.

All photos: Eric Long and Mark Avino for *Star Wars: The Magic of Myth*, exhibition companion book published by Bantam Books. *Star Wars* TM & © 1997 by Lucasfilm Ltd. All rights reserved.

Museum Calendar

Except where noted, no tickets or reservations are required. To find out more, call Smithsonian Information at (202) 357-2700; TTY (202) 357-1729.

October 2 G.E. Aviation Lecture. Chuck Yeager will reflect on his historic flight in the Bell X-1. Free tickets (limit two per person) are available at the Langley Theater box office beginning September 25. Langley Theater, 7:30 p.m.

October 9 National Air and Space Society Lecture. Linda Finch will talk about her re-creation of Amelia Earhart's attempt to fly around the world in 1937. Langley Theater, 7:30 p.m.

October 24 National Air and Space Society Lecture. Retired Vice Admiral Donald D. Engen, director of the National Air and Space Museum, discusses his career as described in his new book, *Wings and Warriors: My Life as a Naval Aviator*. The evening has been designated "Flight Jacket Night," and those attending the lecture are urged to honor aviation by wearing flight jackets. To reserve free tickets, call (202) 357-3030 and ask for tickets for lecture 1Z0-029. Langley Theater, 8 p.m.

October 25 "The Magical Martian Mystery Machine." Find out what Mars looked like 25 years ago. Einstein Planetarium, 6 p.m.

Noontime Concert Series
Join the U.S. Air Force for a musical celebration of the service's 50th anniversary. Every Thursday from Oct. 2 through Oct. 30. Gallery 102, noon.

National Air and Space Society

As a member of the National Air and Space Society, your support will help the Museum's efforts to build an extension at Dulles International Airport, which will display such artifacts as an SR-71 Blackbird and the space shuttle *Enterprise*. To receive additional information, call (202) 786-2643 or write to the National Air and Space Society, NASM, Room 3520-B, MRC 310, Washington, DC 20560.

ERIC LONG

This cockpit instrument panel, removed from the second Republic XP-84, a prototype of the F-84 Thunderjet, looks dated when compared to the slick digital displays found in the cockpits of modern fighters, but in 1946 the XP-84 was anything but. On September 7, the no. 2 prototype set a U.S. speed record of 611 mph. F-84s served during the Korean war and played a key role in the development of in-flight refueling techniques (see "Tankers," p. 24). Donated by the Air Force in 1952, the XP-84 instrument panel, its indicators still luminous with radioactive radium 226, is on display in the Jet Aviation gallery.

Out of the Blue

Mom loved to sing, and she could easily be goaded into breezing through any one of a number of bawdy old airmen's ballads she'd come to know in her Air Force nursing days. In familiar company, it would take only a nudge to send her into a complete rendition of, say, "O'Leary's Bar." Other times she'd get halfway through a more colorful ditty before sputtering to an embarrassed halt, saying, "Well, I don't think I should finish that one in mixed company—but your father would have. And he'd have the whole room singing along."

Dad was a retired Air Force lieutenant colonel who, much to the consternation of his parents, had dropped out of Harvard after 18 months to answer the call of the Korean war. Somehow, he finagled his way into officer candidate school and pilot training, where he earned his bars and wings. He served a brief tour flying F-86s in post-war Korea before ending up at Cannon Air Force Base in New Mexico. There he developed an obsession with airmen's songs. At the officers' club he'd sing enthusiastically, often dragging gaggles of fellow airmen into joyous, drunken choruses. And every time he heard a new one he'd write it down. Ultimately, he amassed hundreds, compiling them in a notebook he called the *Fighter Pilot's Hymn Book*.

Then one day, while paging through a songbook by folk singer Oscar Brand, he was struck by Brand's suggestion that the Air Force was too young to have engendered much of a songbag. The book offered some traditional Army, Navy, and Marine ditties but only one Air Force song, and that one was adaptated from an old Army tune. Dad wasn't about to let this misconception go unanswered. He fired off a letter. "Are you interested in Air Force songs?" he asked. "I am," Brand answered. Brand was unprepared for what soon followed: Dad unloaded his entire collection of 238 songs on him. Singing over the phone, he even supplied Brand with one song's unfamiliar melody.

Brand welcomed the deluge; it was the largest single collection of such songs he had ever seen. But it would not be the last word from the "unsung" fliers of the Air Force. Similarly spurred by Brand's suggestion that the Air Force songbag was young and thin, hundreds of aviators began sending Brand letters, fattening the songbag with favorites of their own.

Eager to record some of the songs, Brand ran the material by Elektra Records producer Jac Holzman, who quickly gave him a green light for the project. When Brand asked Holzman if he should launder the more ribald lyrics, Holzman boldly declined, saying: "Let's make it honest."

The Wild Blue Yonder: Oscar Brand with the Roger Wilco Four debuted in the spring of 1959. It received one of its hottest receptions from my grandmother, who, in a fit of disgust, purportedly scratched one of the more suggestive songs clean off the face of the album.

Not having been born until some years later, I can't attest to the record's popularity among airmen of the day. Certainly I grew up listening to it. But I've always assumed that it turned only in my household, where my father would put it on for some old Air Force buddy and my mother would sometimes object, "Honey, please, not *that* one. At least wait until the kids go to sleep." But we kids never really knew what the songs were about. In fact, with lyrics such as "I wanted wings 'til I got the goddamned things, now I don't want

The author identifies his father in this photograph of an impromptu squadron sing in Korea in 1954 as "second from left, catching flies."

COURTESY JOHN STARR

them anymore" and "Throw a nickel on the grass, save a fighter pilot's ass," we often found them confusing. What was obvious to us was merely the unique air of merriment that seemed to prevail. Had the songs been sanitized, patriotic overtures layered in sentiment, we would have seen right through them. These were barracks songs for men who knew their next day could be their last.

Growing up during my father's second career as a banker, I held the album in special regard. Even before I was a teenager I listened to it, often trying to picture my father as a rowdy jet jockey belting out such colorful laments, sometimes wondering which track my grandmother had obliterated, other times pouring over the write-up Brand gave Dad on the album's back cover. In time, however, my interest waned. I discovered rock 'n' roll, high school, and girls. Shortly thereafter cancer claimed my father, and with his passing I again became interested in the album. But by then it was gone, somehow lost, probably sold at a garage sale.

Operating on a tip that my grandmother had long since come around and was actually quite proud of Dad's involvement in the record's genesis, I dropped her a line. She couldn't find her copy either but thought she could find Oscar Brand; maybe he would have one. Sure enough, on my next visit, she presented me with a copy of *The Wild Blue Yonder*, signed by Brand. She was quick to warn me of its scarcity, quoting Brand as saying, "Here it is. Now you have one and I have one."

I cherished the record. Yet it wasn't until years later that I found stuffed inside the jacket a misplaced lyrics booklet that belonged to a second Air Force album Brand had recorded, entitled *Out of the Blue: More Air Force Songs by Oscar Brand.* Debuting about a year after its predecessor, this album, which I had somehow overlooked all these years, contained not only some of the raunchiest of the ballads from Dad's collection but also a song Dad himself had authored. Judging by the lyrics, I could see it was an unremarkable song. It wasn't even risqué. But it was inspired by an inflight refueling incident that had nearly cost him his airplane and his life. I had to find the second album.

Mom couldn't find her copy, nor could grandmother. I even called Brand. He had one worn copy and couldn't advise me on where to find another. So I started haunting used record stores in Hollywood, where young clerks—many of them struggling musicians, pierced, dyed, and tattooed like mutant butterflies—would look at me as if I had just rolled off a park bench when I explained the nature of the album I sought ("a *military* album?"). They suggested I try thrift stores and garage sales. I did, but to no avail.

One day, while driving through a part of town new to me, I spied a used record store. I dropped in and was floored by the spectacle of thousands of records strewn everywhere, with thousands more stacked to the ceiling on mammoth wooden shelves.

"Is there some order to all this?" I asked a man crouched on the floor, flipping through a pile of classical albums. "Yes indeed," he said. "What are you looking for?"

"Could you point me toward your folk music, um, area?"

"What artist?" he asked.

I pondered the odds for a moment. "I'm looking for some albums by a fellow named Oscar Brand."

He raised his hand and snapped his fingers like a maître d'. "Mike," he called, "show this young man Oscar Brand." An elderly man shuffled from around a corner and led me through a labyrinth of dusty catacombs, packed wall to wall with ancient vinyl. Almost without looking, he came to a stop, reached into a ream of shelved albums, and came out with a stack of records three inches thick. I'll be damned if each and every one weren't first-issue Oscar Brand albums. There were several volumes of the *Bawdy Back Room Ballads* series, a few of the Army, Navy, and Marine compilations, one copy of *The Wild Blue Yonder*, and one copy of *Out of the Blue*, the latter two in excellent condition, complete with lyrics booklets. Not wanting to orphan one album, I decided to buy both. "I'll be wanting these two," I said. "How much?"

"That'll be $35 apiece," the old man said. It suddenly occurred to me that I should have put on a poker face long before I got to this point. I completed the transaction and headed toward the door. "Hey," he called out, a smug look on his face. "You should have haggled. They're collector's items, but I might have come down to $20 apiece."

"Yes, but the loss is yours," I said. "I would have gladly paid $100 for each."

—John Starr

Glendale Rising

The abandoned terminal—the red-tiled roof, the elegant arching portico—is lost among the complexes of a Glendale, California industrial park. The building is all that remains of Glendale's Grand Central Airport and one man's neutral-buoyancy venture. In the history of aviation, a grand total of three all-metal airships got off the ground, and one did it right here.

Thomas Benton Slate, at age 44, had made his fortune on the East Coast as the developer of frozen carbon dioxide, better known as dry ice. In the 1920s, low, slow flight was all the rage, and Slate saw profit and a solution to dirigible defects: fabricate the hull of .011-inch duralumin and dispense with vulnerable fabric skin, leaky gas bags, and a frail internal skeleton. The 200-foot-long hull he envisioned would be an undivided, self-supporting, gas-tight compartment, so hydrogen capacity and available lift would be maximized.

Slate arrived in Glendale in 1925, proclaiming the coming of the airship age to this quiet community northeast of Los Angeles. A regular on the chicken-and-peas civic lunch circuit, he secured a chunk of Grand Central Airport suitable for a colossal dirigible hangar by selling city elders on a future in which Glendale was the "Airship Capital of America." Shares of stock in the Slate Dirigible Corporation were for sale too, and many were purchased by locals. In return for the hometown support, Slate christened his 40-passenger prototype *City of Glendale*.

Glendale's innovations were more than skin-deep. Steam from a flash boiler in the cabin drove a nose-mounted blower at 6,000 rpm. The paddle blades displaced air from the bow, creating a low-pressure zone into which the airship would advance, squirted forward by the wake of higher pressure at the tapered stern. Slate predicted his "air displacement system" would deliver a cruising speed of 100 mph. To boost thrust, Slate added a pusher engine at the stern.

"Sustained flight," another Slate original, referred to the fact that the airship would not land en route. Passenger stops were to be negotiated by an adventurous combination of anchor and elevator. A fuel tank, lowered by a steel cable, functioned as the anchor. Once tethered, a capsule-like elevator would descend along the cable while the airship idled overhead. A thousand-foot boost in Slate's aerial dumbwaiter seemed an unnerving way to make first-class connections; nevertheless, its inventor was confident it would pluck ticketholders from the decks of ocean liners and the rooftops of swank hotels, hoisting them to a cabin furnished with wicker recliners and Pullman-style sleepers.

Proof-of-concept occurred on January 6, 1929, when the airship was walked out of the hangar. At "Captain" Slate's command, a team of handlers began paying out tether. As 5,000 spectators fell silent, *City of Glendale* ascended. In perfect trim, the seven-ton jumbo rose 30 feet to float as delicately as a bubble. Naysayers had scoffed at the seeming contradiction of a craft that was both all metal and lighter than air. But on this perfect day, in this cheering crowd, who wasn't a believer?

Steam turbine glitches kept the ship ground-bound throughout 1929. Finally, Slate turned to a gas-powered Wright Whirlwind engine as a stopgap. On December 17, as *Glendale* glided out into an unseasonably hot afternoon, an explosive hiss shattered the quiet. It was a portentous demonstration of the volatility of hydrogen: The sun's heat on the metal hull caused the 330,000 cubic feet of hydrogen to expand so rapidly that relief valves blew.

Two days later, biplanes carrying newsreel cameramen puttered over the airfield on another hot, cloudless morning. Shortly before 11 a.m., the airship was walked from the hangar with its engines running. Handlers positioned the ship into the wind for launching, but after five minutes of sun on metal hull, hydrogen pressure again soared. A staccato pop of rivets was followed by a clattering boom and a mushrooming vapor cloud as spewing hydrogen met hot air. *Glendale* hung six feet above the ground, port side distended, the duralumin ribs bulging and honeycombed with gaps. Despite a ballast-dumping frenzy, by the time the airship could be tugged back to the hangar, the cabin was plowing a furrow in the dirt.

When a damage assessment prounounced *Glendale* unrepairable, Slate met with sponsors to plead the case for construction of a second ship. But in the wake of October's "Black Tuesday," the stock market had plummeted like, well, a lead balloon, and venture capital had vanished. After the airship was scrapped for 60 cents a pound, the employees were released and the Slate Dirigible Corporation dissolved.

Undaunted, Slate never stopped thinking big. In the mid-1950s he surfaced in Southern California with a proposal to install "cyclone producing devices" atop local mountains to disperse smog, but he was unable to interest officials in the concept.

—Stephen Joiner

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U.S. AIR FORCE

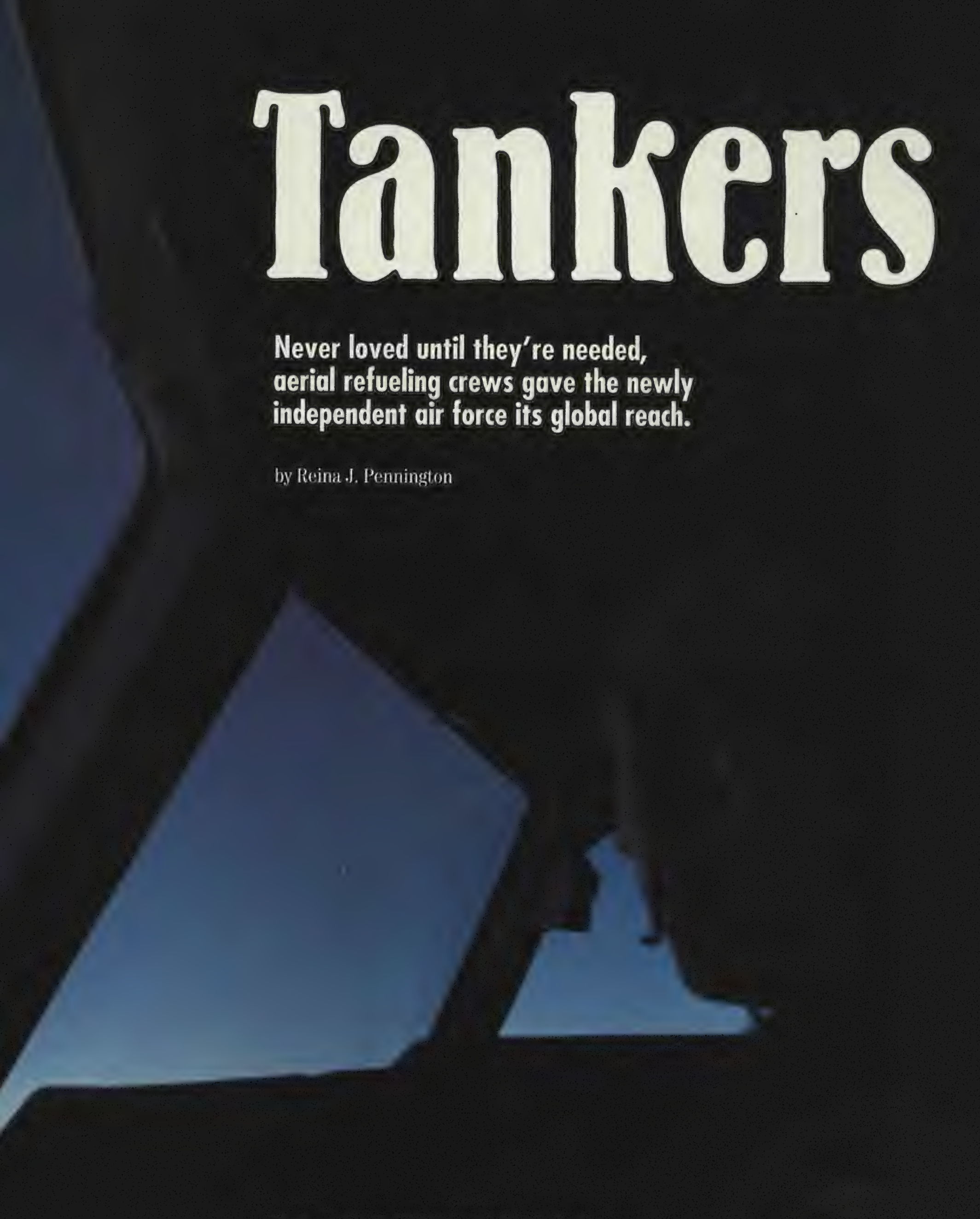
50th ANNIVERSARY

GEORGE HALL / CHUCK SIX

Tankers

Never loved until they're needed, aerial refueling crews gave the newly independent air force its global reach.

by Reina J. Pennington



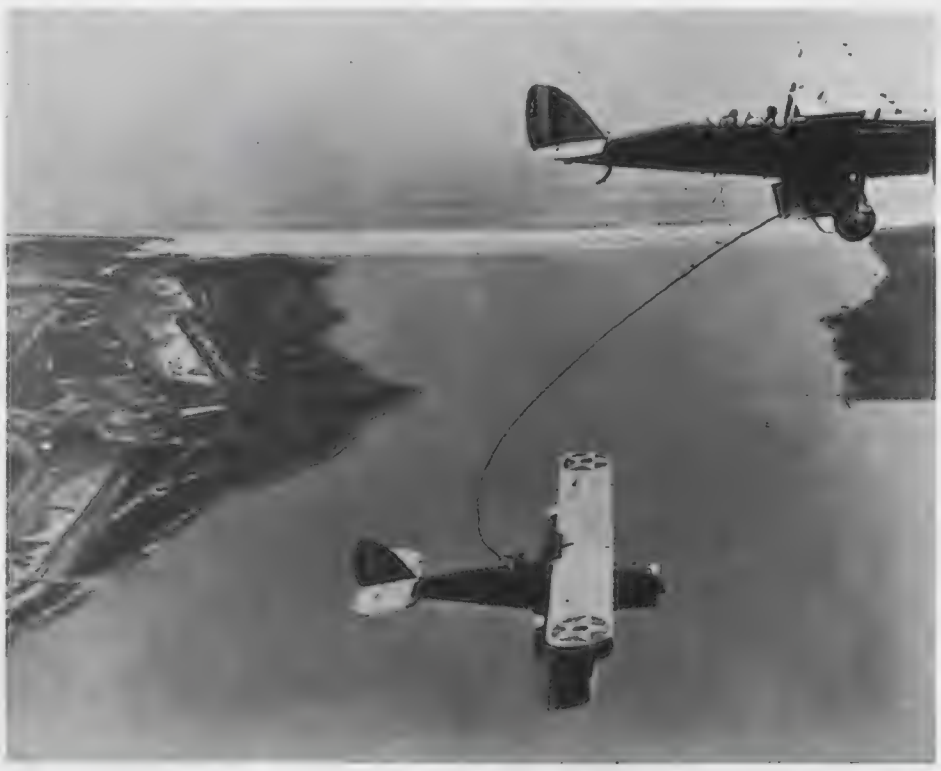
To the pilot of an airplane running low on fuel, the business end of a tanker is a beautiful sight. Here, one KC-10 prepares to refuel another.

The first attempts to refuel while airborne occurred between 1918 and 1921, when U.S. Navy pilots used grappling hooks to snag five-gallon cans of gasoline from floats on the Potomac River. It was thought that snatching fuel from ships would enable aircraft to make ocean crossings. In 1921, the first transfer of gas between two airborne aircraft was accomplished when a wingwalker simply carried a container of fuel from one aircraft to the other. But techniques improved rapidly, and in 1923, Henry H. "Hap" Arnold—then a major in the U.S. Army Air Service—directed the first in-flight hose contact between aircraft.

The watershed for military aerial refueling was January 1929, when an airplane dubbed *Question Mark* stayed airborne for nearly a week. Using a crude hand-held hose to transfer gas, it made 43 contacts with two tankers and set an endurance record of 150 hours, 40 minutes.

The five-man crew of *Question Mark*, all members of the Army Air Corps, received the Distinguished Flying Cross. Several went on to renown: The commander, Major Carl A. Spaatz, became the first chief of staff of the independent Air Force in 1947, and Captain Ira C. Eaker, after commanding the Eighth and Mediterranean Allied Air Forces during World War II, became CEO of Hughes Aircraft. The crews of the tanker aircraft that refueled *Question Mark*, on the other hand, received letters of commendation rather than the DFC. This set an enduring precedent: Although tanker support was absolutely essential to the success of flights like those of *Question Mark*, it would usually be regarded as a less glamorous and somehow less deserving role. And yet the modern Air Force couldn't exist without it.

Hap Arnold articulated a "global mission" for the Air Force even before it was a separate service. He described a force "designed, equipped, and trained to operate beyond the sphere of influence of either armies or navies" in *This Flying Game*, a book he co-authored with Eaker in 1936, shortly before he was named Chief of the U.S. Army Air Corps. Although this vision pre-dated the use of aerial refueling in the Air Force, aerial fueling helped make it possible. "The thinking was always global," says Colonel Phillip S. Meilinger,



The U.S. military saw the potential of aerial refueling soon after it saw the potential of the airplane. The first in-flight experiment, which relied on one aircraft snagging a hose that dangled from another, was accomplished in 1923 by two U.S. Army Air Service de Havilland DH-4s (right). But the flying services didn't seriously pursue the idea until after World War II. In the early 1950s, the Strategic Air Command hosted a test of two refueling methods: the British-developed probe-and-drogue (far right) and the Boeing-developed flying boom (being used to refuel a B-50, top). SAC chose the latter.

REFUELING CHRONOLOGY

1923
Two U.S. Army Air Service DH-4s conduct first successful air refueling; first aerial refueling-related fatality.

1929
Flight of *Question Mark*.

ALL B&W PHOTOGRAPHS/NASM

a historian and former commander of the School of Advanced Airpower Studies at Maxwell Air Force Base. "Refueling made it easier and cheaper." (An essay by Meilinger appears on p. 46.)

Following the end of the cold war, the roles of the Air Force have shifted from the strategic to the conventional, from apocalyptic nuclear war scenarios to a U.S.-based quick-response military, but aerial refueling continues to be the cornerstone of this new global engagement philosophy. "Even today, aerial refueling provides the capability to provide global effects, lethal and non-lethal, in a matter of hours," says Major Dik Daso, current Chief of the Air Force Doctrine Branch at the Pentagon. "Technology has not advanced to the point where limitless fuel supplies, something like cold fusion nuclear reactors, are available. Until this advance occurs, there will always be a need for in-flight refueling."

Air Force strategists consider the refueling tanker a "force multiplier" because it expands the power and reach of combat aircraft, just as if the service had more of those aircraft. The availability of a tanker allows combat aircraft to trade fuel for weapons: An aircraft can take off with minimum gas and maximum munitions, then top off its fuel in the air. Furthermore, the aircraft can stay in the air to the limits of pilot endurance.

Refueling is strictly a support function; tanker crews don't use weapons or risk death in combat. Yet they do make it possible for others to deliver weapons in greater quantities and at greater ranges, and they do on occasion save lives. Moreover, duty on a flying gas station is not without risk. Although tankers normally operate in protected airspace, they still must rendezvous with other aircraft at high speeds, sometimes at night or in bad weather and sometimes under conditions of radio silence. Tanker crews who venture into hostile airspace need courage: Their aircraft have no warning systems, no self-defense systems, and little ability to evade a threat. A tanker is essentially a 300,000-pound gas can—one flak hit could be lethal. A collision with a receiving aircraft could have incendiary consequences.

To be sure, not everyone takes tankers for granted. Certainly not the 13 airmen who were spared a dangerous and possibly fatal swim in the Atlantic in March 1986.

It started as a typical "fighter drag." Two brand-new KC-10 tankers from the 68th Air Refueling Group at Seymour Johnson Air Force Base in North Carolina were using their sophisticated navigational equipment to lead nine Marine A-4 Skyhawk attack aircraft in formation across the Atlantic, providing in-flight refueling as required. The pilot of one of the tankers, Lieutenant Colonel Marc C. Felman, had 2,500 hours in the KC-135, the tanker that for four decades has formed the backbone of Air Force refueling operations, but only six

1934
Flight Refueling, Ltd. founded in Great Britain.

1948
First KB-29M tankers developed; first two aerial refueling units in Air Force established (equipped with KB-29M hose-method tankers).

1949
Lucky Lady II completes the first nonstop around-the-world flight.

Fill 'er Up

Looped Hose

The first aerial refueling technique to be used regularly, the looped-hose method was developed in Great Britain by R.L.R. Atcherly in the 1930s. The tanker stationed itself below and to the side of the receiver aircraft, which trailed a 300-foot line with a pronged grapnel behind it. The tanker then fired a 100-foot weighted line—the contact line—with an attached hose so that it would arc in front of the receiver's line. The receiver reeled in the lines, removed the grapnel, and placed the hose into the receiving tank. The tanker then climbed until it was above the receiver and the fuel was transferred through gravity flow, flowing from the tanker down to the receiving aircraft. In use until the 1950s, this method required relatively low altitudes (below 10,000 feet) and slow airspeeds.

Probe-and-Drogue

In this system, the tanker reels out a hose which ends in a "drogue": a funnel-like basket. The receiving aircraft maneuvers into position to insert its fixed probe into the drogue. Advantages include the minimal equipment required: External pods with drogue reels can be mounted on many types of aircraft. Large tankers can carry several drogue refueling systems and thus refuel several aircraft simultaneously. One disadvantage is that the primary responsibility for making a hookup falls on the receiver pilots. A nervous receiver—such as one flying a damaged aircraft or in bad weather—can have trouble making a connection. The probe-and-drogue system was used on the KB-29M and TAC KB-50J and is used on some C-130s and on Navy, Marine, and all helicopter refueling platforms.

Flying Boom

Developed by Boeing Aircraft in 1948, the flying boom was put into military production the following year on the KB-29P tanker. The boom operator works from a station in the rear of the aircraft and controls the boom by manipulating its ruddervators—the little set of "wings" on the boom that act as both rudder and elevator. Receiver aircraft take an initial position about 10 feet behind and 25 below the tanker. The boom operator then maneuvers the boom into a socket in the receiver's refueling receptacle. When the tanks are full, the boom automatically breaks away. This method is the most reliable, has a higher fuel-transfer rate, and requires less skill on the part of receiver pilots. Flying booms were used on the KB-29P and KC-97 and are used on the KC-135 and KC-10 tankers.

missions in the KC-10. (The first wide-body tanker in military service, the McDonnell Douglas KC-10 is descended from the freighter version of the DC-10.)

Felman and three A-4s took off about 45 minutes ahead of the second KC-10 and the remaining six Skyhawks, headed for an island in the Azores, an archipelago near Portugal. The weather was supposed to be excellent all the way, but as Felman approached the island, fog and rain suddenly developed and visibility dropped to practically zero. The aircraft were instructed to divert to another island, 150 miles away, and finally landed there after three attempts in deteriorating weather. Three of the other six A-4s soon followed. But one of them sheared off part of its gear on lights at the end of the runway, strewing debris, closing the runway—and leaving the remaining KC-10 and three A-4s stuck in the air.

Felman and his crew immediately began loading their tanker with gas. For a while, radio contact was out and no one knew what was happening with the stranded aircraft. When Felman finally got the other KC-10 pilot on the radio, "He didn't want to talk to us, and that's understandable," he recalls. "Later I found out they were preparing to ditch. They had their life preservers on and they were running through the ditching checklist 'cause they were on fumes....It was getting kind of emotional for them."

Felman realized he had to get into the air immediately if there was to be any chance of saving the tanker and the remaining fighters. The fog was so bad that the tower could not see the runway, so the tanker's two crew chiefs stayed on the ground and marshalled the aircraft past the debris and out to a takeoff point. "We threw them their suitcases," Felman says; "I wish we'd remembered to throw them the gas credit card for the airplane so they could have paid for the gas. As it was, we technically stole $80,000 worth of gas from the country of Portugal. But there was no time to say 'How much do I owe you?' " (The bill was paid the following day.)

Within minutes, Felman flew up above the low cloud cover, met the other KC-10, hooked up, and began refueling at an altitude of only 4,000 feet—lower than anyone had refueled before—climbing all the way. He credits his boom operator, Master Sergeant Patrick S. Kennedy, for accomplishing the hookup under harrowing conditions. In 10 more minutes the words "below sea level" would have had a whole new meaning for a $76 million KC-10, three $2 million attack aircraft, and 13 people. After gas was transferred to the other tanker, the KC-10s cycled the A-4s through until everyone received enough fuel to land at an air station in Spain.

1950
First delivery of KB-29P flying boom tanker; first aerial refueling of a jet aircraft (KB-29P to RB-45C).

1951
First KC-97 flying boom tankers delivered; first use of aerial refueling in combat (July 6, 1951, Korean war).

1952
First nonstop transpacific flight (RB-45C refueled twice by KB-29Ps); first transoceanic deployment of fighters (F-84s refueled by KB-29s).

Few dreamed of such feats in the infancy of refueling. Although Spaatz and Eaker had demonstrated the military potential of aerial refueling, nearly two decades would pass before it became an operational reality. Commercial interest in aerial refueling increased during the 1930s, but military involvement waned. The demands of the second world war on both military and civil aviation left little room for continued experiments. Although the Army Air Forces studied several proposals for using aerial refueling in the Pacific, where air operations were severely constrained by the great distances between bases, none was implemented.

In the postwar United States, organizational changes and force drawdowns took center stage for a time. For most aviators, the first order of business was to get independent service status for the Air Force. Many key leaders, including Presidents Eisenhower and Truman, supported the concept. But the use of aircraft to deliver nuclear weapons had reinforced the preeminent role of air power, and the Strategic Air Command was created in 1946—a year before the U.S. Air Force gained its independence. In fact, SAC's long-range bomber capability was the bedrock on which Air Force independence was firmly established. Long range in the mid-1940s, however, meant only as far as a B-29 or B-50 could go, and they were unable to fly from the U.S. to the Soviet Union and back. Overseas bases would be required for any sort of sustained operations, and the United States had learned the hard way in World War II that negotiating the use of bases in foreign lands, even those of close allies, was risky. After strikes in Japan and Central Europe, bombers had been forced to land in China and Russia, and often U.S. officials had to fight to get them back—sometimes without success. Even in friendly situations, bases on foreign soil presented all sorts of potential problems with security and logistics.

Within weeks after the establishment of the independent Air Force, the Heavy Bombardment Committee, an Air Force advisory board, recommended that development of aerial refueling be the service's top priority. As the best candidates for tanker conversion, the committee chose the B-29 and B-36 strategic bombers.

The question of what refueling system to use took a little longer (see "Fill 'er Up," previous page). In 1948, the Air Force bought 35 hose-type refueling sets and reproduction rights from a British firm, Flight Refueling, Ltd., and contracted with Boeing to adapt the sets to the B-29. The use of B-29s as tankers and receivers meant that the U.S. now had the ability to operate against targets in the Soviet Union from bases in Iceland and Alaska—a potent strategic capability.

Early in 1949, the Air Force dramatically demonstrated its expanded capabilities to the world. In February, a B-50A, *Lucky Lady II*, made the first nonstop around-the-world flight. (The first *Lucky Lady*, a B-29, had flown around the world the previous year but had to land to refuel.) In 94 hours and

A stripdown inspection awaited Lucky Lady II *following the B-50's nonstop 23,452-mile flight in 1949, while Generals Hoyt Vandenberg and Curtis LeMay congratulated its pilot, Captain James Gallagher (above, far right).*

1953
First nonstop transatlantic deployment of fighters; first KC-97G delivered.

1956
Flight of first KC-135; last of 888 KC-97 tankers delivered.

1957
First KC-135 delivered; last KB-29 unit in the Strategic Air Command deactivated; *Lucky Lady III* completes the first B-52 nonstop around-the-world flight.

The Navy Experience

Shortly after joining the Navy's VX-3 air development squadron as a project pilot in 1954, I set out to start a program to evaluate the tactical effectiveness of in-flight refueling. The Navy had conducted some tests at its air station at Patuxent River, Maryland, a couple of years earlier but hadn't done much with it since then. I was convinced that in-flight refueling merited closer attention because jet airplanes were notoriously "short-legged" and we needed greater range and endurance at sea.

Only a month after I made my proposal to the Commander Operational Test and Evaluation Force, based in Norfolk, Virginia, the project was given the go-ahead. An AJ-1 tanker was assigned to us for the evaluation, and probes were installed on our fighters. The in-flight refueling packages we were given, however, were the ones left over from the original Patuxent tests. The hoses were brittle and the basket-like fuel drogues the tanker towed behind it were rickety and beat up. Using them was discouraging at times, but as our testing proceeded, it became clear to me that in-flight refueling was going to be not only tactically useful to the Navy, but absolutely necessary.

In late May, I and three others flew to the Vought plant in Dallas to pick up four of the early models of the F7U-3 Cutlass to be used in our tests. (We also used four F9F-7/8 Grumman Cougars.) We returned with those airplanes to VX-3's home in Atlantic City, New Jersey, and modified them for in-flight refueling.

Early in the program, our squadron commander, Hawley "Monk" Russell, took one of the Cutlasses on an air-refueling evaluation flight. Monk had earned a name for himself in carrier aviation during World War II flying early night fighters and had a wealth of aviation experience. He had not flown an air-refueling flight previously, however, so I gave him a procedures briefing.

At 20,000 feet, Monk rendezvoused with the tanker. As he slid his F7U-3 behind the tanker to receive fuel, the tanker pilot dutifully streamed the drogue. Monk was intent on positioning the 24-inch-long refueling probe extending from his aircraft's nose so as to plug into the drogue basket on his first attempt. We found the best method was simply to line up a few feet behind the drogue and just drive the probe into it. This took concentration and coordination. But Monk was concentrating so hard that he failed to see that the old, brittle fuel hose had parted just forward of the drogue and that the drogue was now hanging by only a thin hose-support wire. Focusing fiercely on the basket, Monk plugged in—and then looked in wonder at that small wire. He told me later that his first thought was *How in the hell am I going to get fuel through something as small as that?* In fact, if any fuel had been released, Monk would have had a full bath of it, and one or both engines probably would have caught fire.

TED CARLSON/FOTODYNAMICS

A Navy F/A-18 Hornet cozies up to a tanker's drogue.

He quickly realized that all was not right and backed away from the tanker. As he did, the wire broke and he flew off with the big basket of the drogue firmly planted on the Cutlass' probe. Near where the drogue was stuck, on the left side of the nose, the F7U-3 had an angle-of-attack sensing vane that provided attitude information to the flight control system. Unbeknownst to Monk, the drogue was disrupting airflow to the vane and causing it to feed erroneous information to the controls. In the process of evaluating the flying qualities of his "modified" F7U-3, Monk slowed up the airplane to test it, fortunately at altitude. As he did, the aircraft unexpectedly performed a quick snap roll and scared Monk nearly to death. A voluble man, he let go with a string of invectives that would have curled the hair of any sailor and greatly enlivened the VHF communications channel he was using. By the time he got back to Atlantic City to land, Monk had us all up in the tower to watch. It was a tribute to his flying ability that he got the airplane on the ground.

In flight testing at least half of what you learn is what *not* to do. With that flight, we learned not to fly without first checking the hoses. And we learned the importance of not disrupting the airflow to that vane. But the series of test flights also taught us, ultimately, that jet airplanes could be kept at sea, and that lesson led to the Navy's decision in 1956 that all future fighter aircraft have in-flight refueling capability.

—Donald D. Engen

(Adapted from *Wings and Warriors: My Life as a Naval Aviator*, Smithsonian Institution Press, 1997. Printed with permission.)

1 minute, *Lucky Lady II*, one of 57 B-50As converted to receive fuel through the looped-hose method, flew 23,452 miles and was refueled four times in flight by KB-29M tankers. Its crew (but not the tanker crews) was awarded the Mackay Trophy by the National Aeronautic Association for outstanding flight of the year.

While these flights demonstrated the potential of aerial refueling, substantial challenges in operations remained. Lim-

1961
SAC reaches highest number of assigned tankers in its history (1,095); first Air National Guard refueling wing established.

1964
First aerial refueling in Vietnam war.

1965
Last of 732 KC-135s delivered; last KC-97s retired from duty.

USAF COURTESY DANA BELL

"Longer legs for the 600-mile-an-hour Boeing B-47 Stratojet bomber," proclaims the caption issued with a 1951 Air Force publicity photo of the bomber being refueled by a KC-97 (top left). The long legs increasingly benefitted conventional operations. In 1952, refueling permitted the first transoceanic deployment of fighters—58 F-84s, refueled by KB-29s, flying from Georgia to Japan (left). In Vietnam, SAC tankers performed more than 850,000 refuelings, mostly of fighters (such as the F-4 refueling from a KC-135 in the picture above).

itations in communications, radar, and navigation, for example, made it difficult to get the tanker and receiver to the same place at the same time. In the late 1940s, there were no satellites and few navigation aids or radar sites outside the United States. Aircraft had to rely on fairly primitive on-board communications and on electronics systems with limited range and poor reliability. Pilots could rendezvous by using predetermined times and coordinates, but for a receiver to find a tanker over the Arctic Ocean or the Canadian wilderness was almost like looking for a needle in a haystack.

In 1949, Flight Refueling, Ltd. successfully tested a new system of refueling known as probe-and-drogue. But a technique being developed by Boeing Aircraft, the "flying boom," had already caught the interest of the Air Force. That same year, it ordered that 40 B-29s be converted to flying-boom tankers and be redesignated as KB-29Ps.

About three years later, SAC tested the two methods face to face and chose the flying boom as the best all-around solution. It offered several advantages over the probe-and-drogue. In particular, it could transfer fuel under pressure and therefore at a higher rate, which SAC considered essential for refueling bombers. By 1958, Air Force headquarters had accepted the SAC standard; thereafter, with very few exceptions, all fixed-wing receiver aircraft would be built with boom receptacles rather than probes.

Aerial refueling was first tested in combat in 1951, during the Korean war, when KB-29Ms refueled reconnaissance aircraft and fighters. One year later, it enabled the first mass

1966
56 KC-135As converted to KC-135Qs to handle special fuel for SR-71s.

1968
First tanker casualty in Vietnam war (crash of KC-135 on emergency landing at Wake Island).

1973
Last tankers used in support of combat operations in Southeast Asia.

deployment of U.S. fighters across the Pacific, in combination with island hopping. Previously, deploying a fighter wing overseas meant dismantling the aircraft, loading them onto naval transports, sending them to their destinations, then reassembling them—a nearly three-week process. 1953 brought the first *nonstop* transatlantic deployment of fighters. Two groups of F-84s were deployed from the United States to French Morocco and the United Kingdom. Both groups completed the trip and were ready to fly in less than 12 hours.

Despite the increasing use of tankers in conventional operations, SAC regarded the possibility of a Soviet nuclear first strike as the most serious threat. The first priority for tankers, therefore, was to enable strategic bombers to deter such a strike. As SAC gradually increased the number of bombers on alert status, the number of tankers also increased. By the mid-1950s, the capability of Soviet intercontinental ballistic missiles spurred SAC to set the goal of keeping one-third of its bombers and tankers on ground alert at all times. To shorten response times, entire bomb wings and their supporting refueling squadrons were dispersed and deployed to forward bases, limiting the availability of tankers for nonstrategic missions. Those limits held until the war in Vietnam, when aerial refueling finally became commonplace in conventional operations.

In the meantime, SAC had sponsored another nonstop around-the-world flight. This time a B-52, *Lucky Lady III*, made the trip supported by KC-97 tankers. SAC commander General Curtis LeMay noted the military significance of this feat, saying it demonstrated "SAC's capabilities to strike any target on the face of the earth." But the jet-powered B-52s had actually been slowed down by the piston-engine tankers. Rapid improvements in jet combat aircraft required an improved tanker, and thus the venerable KC-135, predecessor of the Boeing 707 airliner, was born.

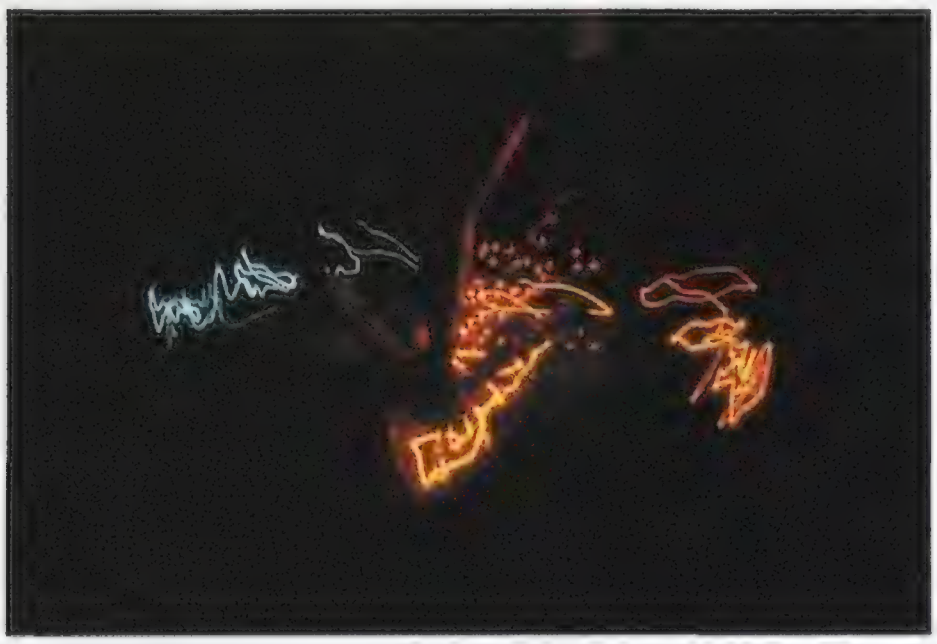
One of the great airplanes in Air Force history, the KC-135 has been the mainstay of the Air Force's refueling operations for 40 years. It proved itself time and again—and not just as a flying gas station. In 1957, LeMay flew a KC-135 from Massachusetts to Buenos Aires—a distance of 6,322 miles—in 13 hours, 2 minutes, and 51 seconds, setting a new world record for a nonstop unrefueled flight. In 1958, SAC KC-135s set a world weight-lifting record, a new speed record for New York to London and back, and several other world records for closed-circuit flights. The 135, under the right conditions, could strut its stuff.

By the time the United States entered the war in Vietnam, LeMay had gotten SAC designated the sole manager for KC-135 refueling operations. For the first time in its history, the command was involved in conventional operations on a large scale. Further, because SAC was able to use the weight it carried in the Air Force to claim priority—ahead of other commands, such as Tactical Air Command and Military Airlift Command—to those airmen who had served combat tours, more and more pilots with tactical experience filled its ranks. Quite a few pilots and navigators who'd started out flying light aircraft in Vietnam found themselves back in the theater on tanker crews.

One such pilot, John Wiley, recalls, "I was banished to SAC along with a bunch of F-100 drivers and assorted other miscreants, and no one was exactly happy to be in SAC." Flying a tanker was regarded as a great comedown from fighters; "tanker toad" was one of the more polite names Wiley was called. "Odd we never heard any wiseass remarks when some F-4 driver was sucking fumes and just praying for some tanker puke to disregard the SAC regs and come a little bit farther north!" he says.

In Vietnam refueling frequently became a matter of life and death. One extraordinary save occurred on May 31, 1967, when Major John H. Casteel and his KC-135 crew adroitly handled a complex emergency. While conducting a routine refueling of two F-104s, the tanker was alerted that two Navy A-3 "Whale" tankers, dangerously low on fuel, were en route. The 135 was topping off the second of the A-3s when two Navy F-8 fighters arrived, almost out of gas. The first A-3 refueled one of the F-8s, while the other fighter, unable to wait for the second A-3 to break away from the KC-135, hooked up to it in a "three-deep" refueling: The KC-135 continued to

A nighttime refueling etches the darkness with the movements of an F/A-18 beneath a KC-135's boom. Although carried out routinely, refuelings at night, in turbulence, in bad weather, and under the constant threat of collision require skillful flying and steady nerves.



TED CARLSON/FOTODYNAMICS

1975
First in-flight refueling of a B-1A bomber;first of 128 KC-135s transferred to Air Force Reserve/ Air National Guard units.

1976
Air Force issues requirement for advanced tanker/cargo aircraft based on existing wide-body commercial freighter. Considers 747, then chooses DC-10 (becomes KC-10).

1980
Air Force begins to modify KC-135As to extend their service life until 2020: the KC-135R features modern F108-CF-100 high-bypass turbofans.

RANDY JOLLY

CHAD SLATTERY

Small rooms, great view: Boom operators ply their trade in the relatively spacious surroundings of a KC-10's refueling station (above right) and the far cozier space in a KC-135 (above). Introduced into service in 1957, the venerable KC-135 (refueling an F-111 at right) is scheduled to serve well into the next century.

GEORGE HALL/CHECK SIX

provide fuel to the A-3, which in turn provided gas to the F-8. Two Navy F-4s also showed up demanding gas; meanwhile, the F-104s provided air cover throughout, requiring additional refuelings themselves. Casteel's KC-135 ended up so short of fuel that it was forced to land at an alternate airfield in South Vietnam. He and his crew later received the Mackay Trophy.

F-4 pilot James D. High recalls a mission over Vietnam in 1970 when a tanker saved his hide. Lacking enough fuel to return to base, he was on his way to a KC-135. About three miles behind the tanker, he checked his fuel again. "I immediately noticed my fuel gauge counter decreasing 2100, 2000, 1900, 1800... going down about 100 pounds a second," he recalls; "not much time left before we became a very poor glider." The problem turned out to be a "reverse fuel transfer." A valve had failed to the "defuel" position and the airplane was actually pumping fuel overboard. "Normally, the tankers did not fly out of Thai airspace," High says. "But tonight, he was 65 miles in Laotian airspace. Decision made, it was tanker or nothing. When he asked how much fuel I wanted, I told him to pump until it quit."

In December 1972, tankers in the theater reached an all-time high of 195 SAC KC-135s, in support of the large-scale bombing of North Vietnam conducted during Linebacker II operations. Tanker navigator Rick Horne recalls one particular mission: "We were lead tanker during one of the night waves on the second day after the bombing resumed. We could see explosions from B-52s getting hit and burning pieces falling apparently slowly, twisting like burning leaves which have been carried aloft from a fire. I will never forget the way that looked, and the realization that there were some of our people in amongst those explosions.

"We were there, flying around like fools with all our lights on so the fighters could see us, well into North Vietnam," Horne recalls. "The North Vietnamese apparently never realized the role tankers played in the air war. They never, to my knowledge, made a serious effort to shoot down any of the tankers. If we'd had to have kept the tankers back, or if we'd had to divert a substantial portion of our force to pro-

1981
First KC-10A enters service.

1982
Southernmost in-flight refueling (performed by KC-10 750 miles north of South Pole).

1996
Longest combat mission in history. On Sept. 29, B-52s fly 36 hours and launch 27 cruise missiles at Iraqi targets during Operation Desert Strike; multiple refuelings by Air Mobility Command tankers make mission possible.

tect the tankers, the air war might have been much more difficult. We gassed some receivers two or three times on a normal mission. If they'd had to return to base each time, we'd have run out of airplanes on most of the big pushes."

From 1964 to 1973, SAC KC-135s transferred 1.4 billion gallons of gas during nearly 195,000 sorties in support of the air war in Vietnam. Even so, most of SAC's tankers remained stateside performing their strategic duties. The demands of routine tanker duty were considerable, as SAC continued to increase its alert posture and to experiment with "dispersal basing"—scattering aircraft at many locations so that they could not easily be destroyed by preemptive strikes against primary air bases.

Looking back on his tenure as SAC commander in the post-Vietnam period, General Russell E. Dougherty identifies two major accomplishments. "In Vietnam we had done 850,000-plus refuelings, mainly of fighters," he points out, "but there were no tankers operating in any of the war plans of any command other than SAC." There were two main reasons for this: the commitment of tankers to support the contingency plan for nuclear war—and the intricacies of determining who would pay for tanker time and gas. These problems were addressed under Dougherty's leadership, and today he feels that "the biggest thing we did in my command was to inject tankers into the operations of the entire Air Force." The second most important change, Dougherty says, was putting tankers in the Air National Guard. When the transfer program was completed in 1978, SAC retained 487 KC-135s. A total of 128 were transferred to the Air Force Reserve and Air National Guard units. This accelerated the shift of tanker usage and control from the strategic to a more flexible, force-wide employment.

Looking to expand and upgrade its fleet in the mid-1970s, SAC decided to adopt a multi-role tanker that could provide both refueling and cargo-carrying capability. Enter the McDonnell Douglas KC-10, which could carry 356,000 pounds of fuel (nearly twice the 135's load) and could accommodate 75 people and 170,000 pounds of cargo. It was also equipped with both flying boom and probe-and-drogue equipment and could itself be refueled in-flight by another tanker (KC-135s at the time could not). The first operational KC-10 was delivered in 1981 and set in motion an important change in the tanker business. "Tanker toads weren't trash haulers until we got the KC-10s," ex-tanker pilot Jon Mickley notes. Now they were required to perform double duty, filling in as airlift in addition to refueling duties.

Limited conventional conflicts increasingly occupied the United States military in the 1980s. The Air Force conducted long-range air strikes against Grenada in 1983 and Libya in 1986 and responded to several other crises, all with SAC tanker support. The demand for SAC tankers soared; more than half of SAC aerial refueling sorties were now flown in support of non-SAC operations.

By the end of the 1980s, even before the official demise of the Soviet Union, it was clear that the cold war was winding down. A nuclear war was no longer the first concern of American military forces. In order to prepare the Air Force for the transitional era to come, in 1990 the Air Force developed the concept of "Global Reach-Global Power," which outlined its changing role in national security. What exactly would be the role of the Air Force after the end of the cold war? Nuclear deterrence was still a priority, but the Air Force headquarters placed a new emphasis on versatility and rapid mobility, both of which would be required by small-scale, regional conflicts rather than nuclear war. The first test of this change in priorities occurred in Desert Storm—the most intensive aerial refueling operation in history.

In the Gulf war, the Air Force averaged 240 tanker missions a day, during which more than 1,000 aircraft were refueled: Navy, Marine, and allied coalition tankers provided another 120 sorties each day. Forty coalition refueling aircraft augmented 300 U.S. tankers—nearly half the U.S. fleet.

Even before the war began, aerial refueling enabled an astonishing *tour de force* of rapid deployment. One of the first steps the Air Force took was to stage tankers at various locations, including the Azores and Cairo, to form an Atlantic bridge from the United States to the Persian Gulf. Transports and combat aircraft were able to fly nonstop, refueling as often as necessary. Over a thousand aircraft were deployed this way, relying on nearly 100 tankers. Most aircraft took about 15 to 16 hours to make the flight, refueling anywhere from seven to 15 times. During the five-and-a-half-month buildup to war, SAC tankers flew nearly 5,000 sorties.

RANDY JOLLY

Tankers were vital to the conduct of the war as well. High-priority targets in Baghdad required cruise missile strikes, which could only be delivered by strategic bombers, and stealth fighter-bombers. But logistics and security issues prevented basing B-52s in forward areas. No problem: the B-52s could simply fly from their home bases in the United States or from safe locations like the Diego Garcia U.S. air base in the Indian Ocean. For example, on January 17, 1991—

JIM BENSON/CHECK SIX

A B-52 (above) and an F-15 (left) gulp gas from KC-135s. Because of SAC's long-time emphasis on training for nuclear first-strike deterrence, tanker crews were as likely to train with SAC's bombers as with the 12-times-larger Air Force tactical fleet. Some have said this created a weakness in the performance of tanker crews in conventional operations, which became apparent during the Gulf war.

the first night of the war—cruise missiles were delivered against targets in Baghdad by B-52s flying directly from Barksdale Air Force Base in Louisiana to Iraq.

Aerial refueling made another, more unexpected, contribution during the conflict in the Gulf: The operation revealed that for all their successes, SAC tankers were not well prepared for an intensive conventional war. Despite the fact that the only combat SAC had ever experienced was conventional, the primary emphasis in its training had been for nuclear war scenarios. Tanker crews spent as much training time with 250 SAC bombers as with the more than 3,000 Air Force tactical aircraft. Passing fuel to bombers on intercontinental attack profiles involved predictable patterns: well-rehearsed rendezvous procedures, known quantities of gas, a measured pace, and a relatively low ratio of receivers to tankers. Refueling tactical aircraft in a dynamic combat environment was something else entirely. Although pre-strike refuelings were closely planned, all sorts of things could go wrong thereafter. Fighters burned varying quantities of gas during a mission, depending on weather and on time spent in afterburner, avoiding threats, reattacking targets, or chasing down the enemy. If a fighter was damaged in combat, it might leak fuel or be forced to jettison external tanks. It might not be able to reach the designated refueling areas. In addition, basic communications procedures used by tactical aircraft differed considerably from those used in SAC, and tanker crews were often unfamiliar with them.

Another complication was that airspace in the Gulf region was congested. Some 45 designated refueling areas were established and required close scheduling and monitoring. Scheduling was particularly complicated because of the need to match refueling equipment. If a non-Air Force or non-U.S. aircraft needed refueling, it had to be provided by a tanker equipped for probe-and-drogue. This was no problem for the dual-equipped KC-10, but KC-135s had to be fitted in advance with drogue adaptors and therefore were limited on any given sortie to refueling only one type of receiver.

Some fighter pilots who flew in Desert Storm criticized the tanker support they got. One F-15 pilot who prefers not to be named believes that the tankers were inadequately prepared for dealing with the crowded and chaotic conditions of wartime refueling. "During the first few days, we used the 'big sky theory' in the clouds," he says, meaning the idea that there's room enough for anybody. "With hundreds of us out there at the same time, amazing that nobody smacked into anyone else." Moreover, he says, "On the whole, I wasn't too impressed with the SA [situation awareness] of tanker crews—lots of inflexibility and questionable airmanship...tanker pilots were reluctant to cross the border into perfectly safe areas; others were flying at night well into Iraq *with their lights on!*"

TED CARLSON/FOTODYNAMICS

An intimate view of an F-117 being refueled shows the location of the stealth fighter's air refueling receptacle: above and behind the cockpit. Opposite, a KC-135 leads a trio of F-15s and an E-3 AWACS (Airborne Warning and Control System).

Brigadier General Richard C. Marr, who commanded a refueling wing during this period, acknowledges that there were shortcomings. "The tactical doctrine of air refuelers was not built for contingency operations like the desert war, because for generations we had been encumbered by a focus on nuclear mission support. And when you go out to refuel a strategic bomber, a B-52 or a B-1, the procedures are a lot different than when you go into a very rigidly managed airspace to refuel fighters. It's one heck of a big difference. I would say that our heritage of coming through the Strategic Air Command, and the emphasis on supporting bombers, did not enable us to have our crews as tactically honed as they should have been to support that war, although we did it, based upon the wonderful expertise of the individual crew members."

Major David Horton's experience flying a KC-135 on the second night of the war is one such example. There was a severe storm that night, the worst weather in the region in 14 years, and he picked up a distress call from an F-117. Returning late from an attack on Baghdad, the stealth fighter had missed its scheduled tanker and was critically low on fuel. Refueling the 117 required special procedures. For security reasons, most refuelings were accomplished with minimal communications, but for a tanker to achieve a visual rendezvous with a stealth fighter at night is tricky, to say the least. Further, the 117 pilot has a limited field of vision through the cramped windscreen. Luckily, Horton and his crew were qualified for F-117 refuelings and had a full load of gas. "We called AWACS and told them that we had the gas if he had enough time to get together with us," Horton says. They headed for the Iraqi border. "I found out afterwards that AWACS was contemplating turning us at that point to keep us from going into Iraq, but better judgment prevailed," he recalls. "By the time we hooked up, we were about 60 miles deep in Iraqi airspace, lit up like a Christmas tree because we had to [be] in order for him to see us in the weather we were in." Conditions were so severe that Horton's boom operator couldn't even see the 117 at the end of the boom.

By the time they finally hooked up, Horton says the F-117 had less than 100 pounds of gas left on board. The pilot "told my boom operator that he basically had one shot at this or he was going to have to [eject]," Horton recalls. "That would not have been the optimum place to lose a 117."

They achieved a second hookup as the aircraft turned south and started descending, finally emerging from Iraqi airspace. As the 117 took on fuel it had trouble maintaining altitude and retaining the hookup so Horton tobogganed his big tanker—descending with the fighter as both traded altitude for airspeed—enabling the fighter to stay with him long enough to take on a full load of fuel. "We found out afterwards that one reason he was having trouble holding altitude was he had a weapon on board, so he was a whole lot heavier without any gas," says Horton. "And flying at a high altitude, especially at the airspeed we were flying, was extremely difficult for him." As the stealth pilot disconnected from the tanker and headed to base, he told Horton and his crew, "You guys really saved my bacon."

During the 43 days of combat in Desert Storm, the coalition tanker fleet performed some 50,000 refuelings and transferred more than 700 million pounds of fuel. Phillip Meilinger, a member of the Air Force division responsible for the design of the air campaign during the war, points out, "There were thousands of aerial refueling sorties during Desert Shield and Desert Storm and not one mid-air [collision]. That's awesome. They must have been doing something right."

The Air Force is still studying the lessons learned. One thing is clear: Desert Storm would have been quite a different war without aerial refueling. It was refueling that allowed coalition forces to maintain the pace and intensity of operations. In many ways it was the tankers that determined the parameters of the air war; aerial refueling was both a limiting factor and an indispensable asset. Major General Hal Hornburg, who commanded a composite fighter wing in Desert Storm, says: "You never, in a combat operation, have enough tankers. [The] planning factor for tankers, which I've adopted, is to plan to the most minute detail the number of tankers required for any air operation, and then if possible, double it."

After the Gulf war, the Air Force underwent a massive reorganization. Both the Strategic Air Command and Tactical Air Command were merged into a new Air Combat Command. Their airlift and air refueling assets were assigned to a new Air Mobility Command. In 1992, AMC opened the Tanker Airlift Control Center, which now provides "one-stop shopping" for planning and directing tanker and transport aircraft operations around the world. It also created the Air Mobility Warfare Center at Fort Dix, New Jersey, under the command of Brigadier General Richard C. Marr. "The AMWC is like graduate school," says Marr. He says the experience of Desert Storm is very much taken to heart, and changes have already been made in tanker tactical procedures. For example, tanker formations—the vertical and horizontal distances between aircraft—were originally established for refueling bombers in friendly airspace, with sufficient space between tankers to allow the big bombers to get in and out easily. But those formations don't work well in situations like that found in Desert Storm, where tankers needed to be more closely spaced to allow more efficient management of the airspace and to allow groups of fighters to stay more closely in formation while refueling. So new "reduced interval" formations have been developed that are better suited to today's tactical environments.

There are plenty of disputes about the future of aerial refueling. Some argue that in the interest of efficiency, all tankers should be built on the KC-10 concept, offering both cargo and refueling capability and both boom and probe-and-drogue technology. Some argue that the Air Force needs more multi-point refueling capability—the ability to refuel several receivers from the same tanker simultaneously—to increase flexibility in conventional scenarios. Any new tanker will run in the neighborhood of $100 million per aircraft; with today's budget constraints, it likely will be years before the KC-135, an ancient aircraft by anyone's standards, can be replaced.

Despite the continuing limitations in the Air Force refueling fleet, it is still the world's best. During the dissolution of the Soviet Union, many tanker units ended up under the control of newly independent former republics, like Ukraine. The Air Force of the Commonwealth of Independent States tried hard to get them back. In 1992 the commander of the CIS Air Forces was quoted in the Russian press as saying, "Pardon my unparliamentary language, but bombers without tankers are like eunuchs." No air force has a credible global capability without tanker support.

RANDY JOLLY

Airline mechanics wage war on cracks, corrosion, and coffee.

20,000-Hour

At Delta's Technical Operations Center in Atlanta, well-worn airliners are stripped, repaired, and reassembled to fly again.

Tuneup

by Carl Hoffman

Photographs by Cameron Davidson

and by Erik Hildebrandt

C.D.

Crawling through what used to be the galley of a Northwest Airlines 747-200, a spray bottle of alcohol in one hand and a rag in the other, James Inman grinned impishly and said: "If we'd put all the passengers on an IV and a catheter we'd be in great shape."

Inman, an FAA-licensed airframe-and-powerplant mechanic, was only half joking. Just seven days earlier the giant 18-year-old airplane in which he was toiling was shuttling hundreds of travelers at a time across oceans. Now, the main cabin looked like the inside of a long tin can. The seats were gone, as were most of the floor, sidewall paneling, and galley and lavatory walls. Over the course of the airliner's 13,000 flights, hundreds of thousands of passengers had in fact not had the benefits (from Inman's decidedly non-customer-oriented point of view) of an IV and catheter. The results, revealed below Inman's feet, were not just unsavory but possibly even dangerous: The aluminum floor beams underneath the former lavatories and galleys were sticky, black, grimy, and reeked of urine and coffee. And thus, perhaps, riddled with corrosion, the bogeyman of all jetliners. As Inman cleaned the beams, a Northwest inspector stood waiting, armed with flashlight and dental mirror, to survey the damage.

Welcome to the D check, a heavy maintenance inspection that may require multiple, scheduled visits, and that is essential to the safe operation of ever-aging commercial jetliners. After just one week in Northwest's 747 check hangar at the Minneapolis-St. Paul Airport, airplane number 6626 looked like it would never fly again. A tangle of scaffolding and catwalks surrounded the wings, tail, and fuselage, which rested on mammoth yellow jacks. The four engines were gone, as were their pylons. On the airplane's upper deck, the cockpit and first class cabin were a rat's nest of exposed wires, while elsewhere insulation dangled from the ceiling and yellowed newspapers, soiled napkins, and assorted tools littered the floor—where there still was

E.H.

Heavy maintenance involves removing everything that makes the interior of a fuselage look and feel like a living room. It's really a complex, 600-mph metal tube (above). Flight controls are inspected, adjusted, lubricated, or sometimes replaced (below).

C.D.

a floor. Thousands of little circles and squiggles in red grease pencil, from the nose to the tail and everywhere in between, highlighted areas of potential damage or wear. But somehow, if everything went according to plan, in just 27 days—that is, after 38,000 planned hours of labor, tens of thousands of unplanned hours, the completion of a checklist some 5,000 pages long, and the repair of some 1,600 unexpected, or "non-routine," discrepancies—one quarter of the D check (called a C check) would be complete, and 6626 would fly again.

Time-consuming, expensive, logistically daunting, D checks are the most thorough of the periodic maintenance checks that all airliners flying in the United States must undergo. Exactly what is done to an airplane, how often, and for how long all vary widely among airlines and airplane types. A Northwest Boeing 747-200 comes in for one quarter of its D check after every 6,200 hours of flight time, while a Delta MD-88 might come in for what that airline calls a heavy maintenance visit, or HMV, at 19,000 hours, after less intensive half-C checks every 1,750 hours.

When an airplane is delivered it comes with its own operating manual, written by what's known as the Maintenance Review Board, which is composed of representatives from the airplane manufacturer and the Federal Aviation Aministration. Like a car manual, the MRB recommends which tasks are to be done at which time intervals, and the tasks and times differ for every type of airplane. They range from replacing so-called hard-time items like engines, flaps, fuel pumps, and landing gear, all of which are changed after a set number of hours or takeoff-and-landing cycles (a Delta MD-88's landing gear is changed every 22,500 cycles or 10 years, whichever comes first, for instance), to ever deeper and more thorough inspections and maintenance of the airframe itself. And as an airline gains experience operating its fleet, it develops its own schedule for maintaining the aircraft. "Each operator has a different, unique twist to how it inspects and maintains its aircraft," says David Cann, acting manager of the FAA's aircraft maintenance division, "because different airlines have different operations and experiences. One may be starting to use a 767 for the first time, while another may have been using them for a decade." In addition, FAA Airworthiness Directives often require new maintenance or modifications not originally called for by the initial MRB, and these new requirements may or may not fit in with regularly scheduled letter checks. All of which makes for a confusing array of names—Q checks (at US Airways), D checks, multiple C checks, Heavy Maintenance Visits—for essentially the same thing: Every airplane is opened up, cleaned, inspected, modified (if required), reassembled, and checked, then out the door it goes to carry passengers again.

With young narrow-body airplanes the process might take 12 days and as few as 8,000 man-hours of labor. With an aging wide-body Lockheed L-1011 or Boeing 747,

the figures get mind-boggling. A recently inspected Northwest 747, which was a 28-year-old workhorse and on a different inspection program for older airplanes, took 65 days and 90,000 man-hours.

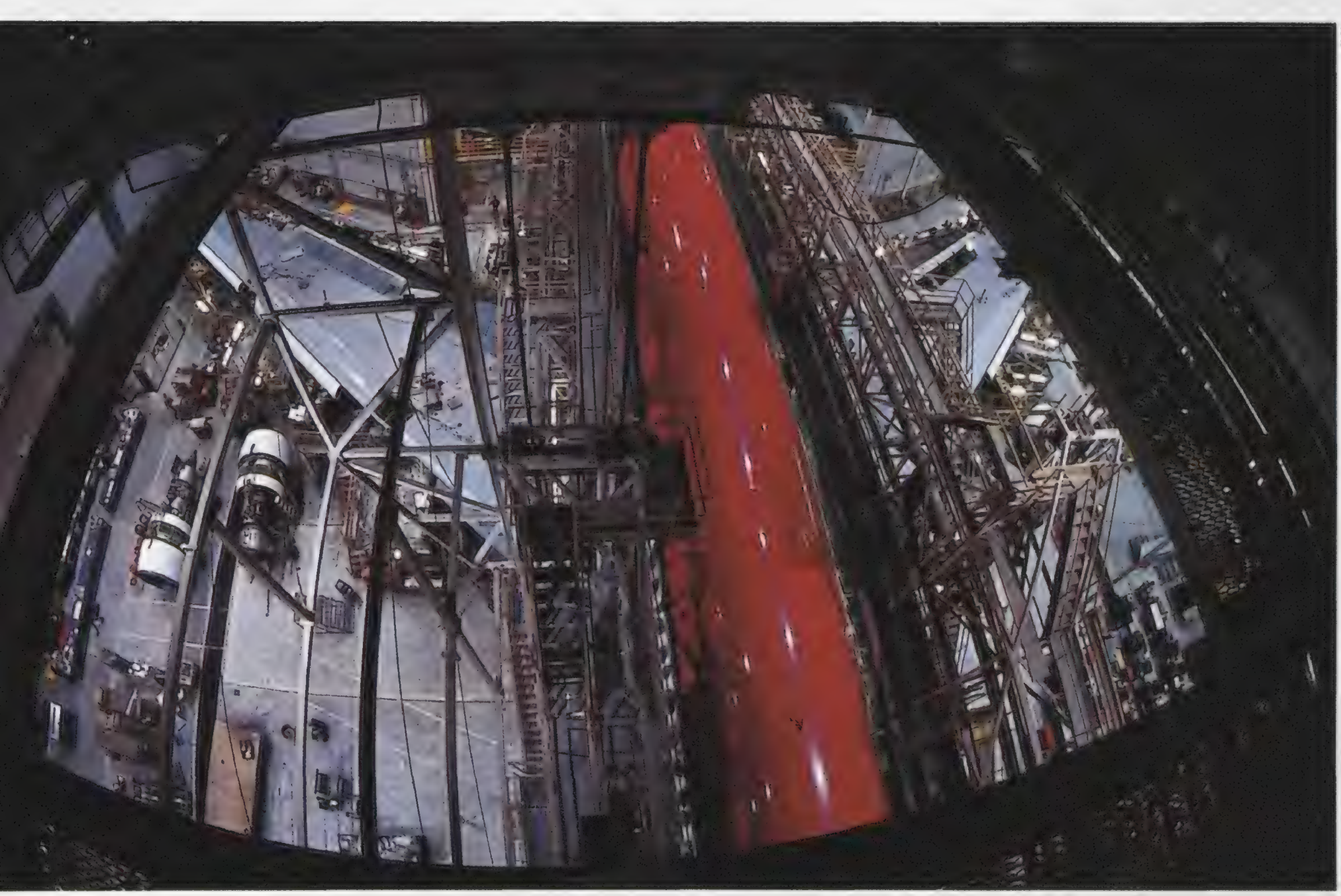
Last June, Delta Airlines aircraft number 977, an MD-88 built in July 1991, rolled into Delta Technical Operations Center one, bay three, at Atlanta-Hartsfield International Airport. The hangar, 600 feet long and eight stories high, is one of three at "Tech-ops," a vast, timeless place covering 150 acres where three shifts of mechanics work 24 hours a day and zip between hangars and shops on bicycles and golf carts. A fairly new airplane, 977 had thus far come into the hangar for half-C checks every 1,750 hours. During the relatively brief 14-hour inspections, mechanics scrutinized the outside of the fuselage, lubricated the flight controls, and performed other maintenance on hydraulic and other systems. Now, after 19,000 hours, it was time for its first full Heavy Maintenance Visit. (As airplanes age the time between checks often shrinks; 977's next HMV would come in another 11,000 hours, says Delta's Ed Toth.) The aircraft's maintenance cards had been pulled three weeks before—thousands of them, color-coded by work area, each detailing an item to be checked or serviced, and any modifications called for by the engineering department or by marketing, which might call for new fabrics, color schemes, or repositioning the seats to add more (or less) leg room.

Looking inward: Marty Cintron uses X-ray images to search for hidden damage in an engine combustion dome (below).

C.D.

Inspector Stewart Fitzhugh, about to start examining the right side of the fuselage below the floor line, was a mechanic first; at Delta inspectors average 17 years of experience. "I'm looking for skin bulges, missing or loose fasteners, anything that might be a sign of corrosion," he said. "The front and aft lav panels, the cabin doors, all the cutouts—any opening needs to be looked at pretty carefully." He started at the nose and peered at the shiny sides and underbelly with a flashlight. Using a red grease pencil and deck of cards, he wrote up the

The big picture: Some 747 inspections require 90,000 hours of labor.



E.H.

The fluids in an airliner's lavatories and galleys can corrode floor beams (above).

C.D.

After shimmying into a cowling, Delta's Tom Fairchild checks out a high-bypass turbofan.

"discrepancies" or "non-routine items" that he discovered. Mechanics would come behind and fix exactly what the inspectors indicate. Later, the repairs themselves are inspected and approved.

Fitzhugh worked his way aft, taking nothing for granted. He marked a particularly dirty spot on the underbelly, which might signal a hidden crack, for an extra washing and reinspection. He found five fasteners loose near the nosewheel and discovered that the drinking water hatch fit loosely and the latch had a broken spring. He marked every gouge and dimple in the airplane's skin, and there were dozens of them, especially around the doors and baggage compartments. "Ninety percent of this damage is done by ground personnel," he explained.

Within a few days every exterior surface of the airplane, from wings to flight controls to landing gear, would be similarly checked. With carbon composite flight controls on Boeing 767s and 757s, inspectors will also perform a tap test, a surprisingly low-tech means to diagnose trouble on a sophisticated airplane: tapping a screwdriver handle along the surface to identify places where the carbon might be delaminating.

By midnight, Delta 977's seats and carpets were gone, the lavs and galleys were coming out, and the airplane smelled like a late-night diner with dirty bathrooms. "Taking apart the galleys and lavs is nasty," shouted mechanic Charles Cinque above the clamor of screw guns, Van Morrison on a boom box, and work teams removing side panels and floor boards with remarkable speed. "You can pull out the galleys and find a tremendous stench, and in the lavs you find a lot of stray blue juice and soggy toilet paper." Cinque has found nesting mice, cockroaches, even, he said, "a brick of drugs" in one of the lower baggage compartments.

The importance of getting underneath the galley and lavs, however, was evident in a young 767 in the next hangar. There, sheet metal mechanic Scott Weiss was replacing an aluminum floor stringer and adding a titanium doubler on the beams under the lavatory floor. The old piece, cut out, lay next to him, pitted, gray, corroded nearly halfway through from a nasty cocktail of human waste and coffee. "They're overpowering

liquids and the corrosion they cause will tear apart an airplane," he said.

The zealous war against corrosion, more than any other single thing, is changing the way airplanes are maintained, and it dates to one incident. In 1988 a large piece of fuselage skin separated from an Aloha Airlines 737, killing a flight attendant and traumatizing passengers who spent the final minutes of the flight strapped to the seats of their partially roofless airplane. The resulting investigation report issued in 1989 by the National Transportation Safety Board attributed the accident to the failure of the Aloha maintenance program to detect the corrosion that caused the accident. The NTSB also faulted the FAA for not thoroughly evaluating Aloha and for not responding to indications of problems involving fuselage joints on some 737s. The event highlighted the increasing age of the world's airliners—Boeing predicted that 250 to 300 airplanes would be retired in 1988, but the total turned out to be only 60.

In response, Congress passed the Aging Aircraft Act in 1991, which required, among other things, detailed corrosion studies. "Fatigue is not nearly as difficult as corrosion," says Delta's Ray Valeika. "Fatigue is predictable with analytical studies, but corrosion tends to be random—not in where it occurs, but in when it occurs." As Valeika says, "Corrosion doesn't want to wait," which is why Scott Weiss was replacing thick aluminum floor stringers on a relatively young 767 and the FAA has mandated that all aircraft now have corrosion prevention and control programs that bring airplanes in for more thorough maintenance visits more often. Airlines must carefully coordinate all aspects of the maintenance schedule, including regular letter checks, Airworthiness Directives, and corrosion inspection requirements in the most efficient and cost-effective manner, said Fred Amyotte, a Northwest 747 maintenance check foreman. Today, many airliners continue to fly well beyond their originally forecast lifespan of about 20 years; keeping these aircraft safe requires more frequent inspections.

Maintaining an airliner requires sophisticated diagnostics, but skilled mechanics and hand tools get the job done (below).

C.D.

A 747 stretches its legs above the hangar floor. Retraction tests are done after gear maintenance, or during adjustments to the doors.

The mechanics continuing to practically dismantle the 747 in Northwest's Minneapolis hangar had no time for lofty discussions of aviation policy—there was work to do. Letters flashed across a sign that keeps track of the 747's progress: "Day 7 of 35. Opening for cleaning and initial inspection. Initial is 89 percent complete. 1,369 non-routines reported; 122 non-routines complete." As is often the case with heavy maintenance visits, 6626 was in for a host of overlapping maintenance requirements that had been bundled together: a standard letter check and two FAA Airworthiness Directives.

E.H.

Northwest breaks its 747 D checks into four segments, or C checks, so that about every six years it will have completed one D check. It was as part of a standard C check that James Inman was cleaning the floor beams around the mid-galley and lavs. The grime cleaned, lead inspector Ed Nelson went to work. "It's not a job you can hurry up

E.H.

Warning tags hanging from cockpit controls in a Northwest 747 mark systems undergoing maintenance (right).

C.D.

Mark LaGasse scrapes paint in the wing tank of a Delta L-1011. This snug access port is both the way in and the way out.

and do," he said, crouched on a battered seat cushion to check the bottom and top of each stringer and frame with a flashlight and oversized dental mirror. Nelson, 54, wearing a red Northwest baseball cap and black tennis shoes, started with the airline as a mechanic in 1969 and became an inspector 10 years later. "Experience makes a world of difference," he said, examining the underside of a beam. "Look!" He showed a rivet head sheared off. He marked the spot and noted it on a pad.

Every crack, if it's not on a self-contained part that can be replaced, will be further analyzed with non-destructive technology—usually through a process known as eddy current testing, in which a high-frequency electrical current is sent through the part, revealing exactly where the damage starts and ends, which can be impossible to see with the naked eye. Although eddy current testing has been used for several decades, other, more sophisticated methods of examining airplanes without taking them apart are the great hope of the industry. "We haven't touched the surface" of what can be used to inspect an aircraft non-invasively, says Valeika, who looks forward to the day when "you'll be able to take a holographic picture, like a CAT scan, and see the stress and strain and surface deteriorations" instead of relying on the human eye.

As yet, however, nothing can replace people like Ed Nelson, who says that the older the airplane, the better its foibles are known. "You get a brand-new airplane, you don't know what you're up against," he said, identifying one of the fundamental and unfortunate aspects of aircraft maintenance. Inspectors rely on history and experience. With new aircraft, they can only hope that they discover defects or design idiosyncracies, before such faults cause an accident. Such is the case with the 747's upper deck forward section just behind the cockpit, which was identified as a potential problem in 1986, 16 years after the aircraft type entered service. Section 41, as it's formally known, has broad, flat sides that want to go round during cabin pressurization. So badly and routinely do its frames and stringers crack that the FAA issued multiple Airworthiness Directives detailing specific Section 41 areas to be inspected and repaired at intervals of 10,000, 13,000, 16,000 and 19,000 cycles. Although it's often done earlier, replacement of parts is not actually required until 20,000 cycles, when, "you either replace all the frames in the section or park the airplane," said Fred Amyotte. Number 6626 is no exception. At this 13,000-cycle check—scheduled so that it would overlap the quarter C, during which the airplane would already be ripped open—numerous three-foot cracks were discovered, necessitating the replacement of several frames, each of which had as many as 100 rivets that had to be popped out before the cracked frame could even be removed.

But sometimes airlines and manufacturers

Airliners are scrutinized from their tires to the tops of their vertical stabilizers (below). Delta mechanics use strong chemicals to remove accumulated grease and grime from inside the wing of a 727 (bottom).

E.H.

have no inkling of a problem until disaster strikes, forever altering an airplane's inspection and maintenance routine. The biggest single task on 6626, for instance, was the strengthening of its four engine pylons resulting from FAA Airworthiness Directives issued in response to cracks found in engine pylons and incidents involving 747 engine separations, some of which led to crashes.

The pylon modifications are a massive 32-day task (Northwest has a total of 40 747s to modify) requiring precision machining and drilling of expensive titanium parts (one, a mid-spar fitting, costs $65,000) and equally precise assembly, some of which has to be done from within a wing fuel tank only 12 inches high. "Some holes have to be done with a mirror and some you've got to be lying upside down in the tank and it all has to be done right," said crew leader Doug Selby, standing on a long platform cluttered with toolboxes and ladders under the wing. Only the smaller guys like Bob Sullivan can squeeze into the wing tanks. "When the plane first comes in and the fuel is sumped out it's pretty bad in there," Sullivan said.

The work continues as the work cards spell out a relentless string of tasks. "Sheet Metal Related, Right Wing: Group I: Check/replace right leading edge flap bonding straps for condition and replace frayed or damaged straps..."

There are 5,011 pages of routine work items for the Northwest 747, from the mundane to the critical. Step by step, the tasks are designed to exorcise every crack, ding, and bubble of corrosion and put every rivet, nut, bolt, fuse and wire back into place. Unlike that car you rebuilt in your garage, there can't be any pieces left over.

C.D.

COMMENTARY:

The Next Air Campaign

The use of airpower has always held out the promise to win wars more quickly and at lower cost in both blood and treasure than more traditional forms of warfare. However, for 75 years it has often failed to live up to the claims of early theorists and their most ardent supporters. It hasn't been ineffective or a failure; rather, airpower simply did not deliver as much as its champions had promised.

Airmen traditionally dismissed such criticism by noting that we did not yet have the technology necessary to fulfill these promises, or that the other military services, which dominated strategic decision-making, were not allowing airpower the opportunity to demonstrate its capabilities. When technology caught up with the theories and when airpower was given its independence, they argued, it would become the ultimate weapon.

Airpower was born in World War I, at the height of defensive dominance on the battlefield. That conflict was the most brutal and deadly in memory. An entire generation of European men died in that war, and the total death count reached 15 million. Even the victors were decimated.

During the next two decades, military thinkers sought ways and weapons to win wars at a lower cost. Airpower seemed to offer relief from the horrible attrition of the first world war. Military strategists regarded airpower as an inherently offensive weapon that could strike immediately and effectively at an enemy's vital centers, eliminating defensive stalemate. Few airmen ever claimed airpower alone could win wars, but they were convinced that it had revolutionized the conduct of war. General Billy Mitchell's bold statement in 1930 was typical: "Nothing in the world's history has brought about as great a change in the employment of military power as the coming of the airplane."

But in World War II airpower yielded a mixed result. As General Dwight Eisenhower noted, there would have been no D-Day without Allied command of the air. The employment of tactical airpower was similarly acclaimed, especially when it had been conducted in close cooperation with ground forces: Fighter-bombers—whether German, Soviet, British, or American—were enormously successful at knocking out enemy positions.

But virtually all airmen, regardless of nationality, thought that the use of airpower in a tactical role denied the airplane its most important assets: speed, range, and flexibility. To them, airpower's unique advantage was its ability to strike strategically. Using it only to complement the surface battle negated this advantage.

The results of strategic bombing were not as obvious as the accomplishments of tactical airpower, however. Although German industry had been subjected to massive destruction and dislocation, the process had required far more bombing and incurred a far greater price than airmen had predicted before the war. Nearly 160,000 British and American aircrew were lost over Europe. The attrition of trench warfare had not been eliminated—it was merely moved to 20,000 feet.

The situation over Japan was somewhat different. Nearly 95 percent of all bombs dropped on Japan fell in the last five months of the war. By August 1945 Japan's major industries were virtually gone. The two atomic strikes finally induced the emperor to surrender prior to a potentially costly November invasion. The oft-repeated promise of airpower and its ability to

DAVID POVILAITIS

Phillip S. Meilinger cautions that airpower—once oversold—is now in danger of being undersold.

end wars more quickly and with less loss of life had been demonstrated.

When the U.S. Air Force was formed in the aftermath of World War II, it appeared that we had the technology—in the form of the atomic bomb—to support the theories of airpower. But although "massive retaliation" backed by atomic airpower was a viable deterrent, conventional war required a more discriminating tool. This became painfully clear in Korea, where, despite airpower's ability to dominate the battlefield, it was powerless against unreachable strategic centers. The true pillars of North Korean strength were located in Manchuria and the Soviet Union, both of which were politically off limits to U.S. airpower (and rightly so).

For airmen, the frustration caused by enemy sanctuaries and limits in the application of airpower increased dramatically during the Vietnam war. Many believed that if a true strategic air campaign had been attempted earlier, or if the technology had been more effective, the war would have turned out differently.

The Persian Gulf war seemed to fulfill the airmen's promises when a five-week coalition air campaign relentlessly pounded Iraqi forces and paved the way for the conclusive ground assault, resulting in the most lopsided victory in modern history. During the Gulf war, airpower was effective at both the strategic and tactical levels. From the first night of the war, airstrikes shut down the electricity in Baghdad. Even if there had been power, Saddam Hussein was denied the ability to talk to his people: The television broadcasting antennas were also down. Transportation was seriously disrupted, with frontline Iraqi troops in Kuwait almost totally cut off from reinforcements and supplies. Thousands of tanks, artillery pieces, aircraft, and trucks were destroyed before the ground operations even began. When the coalition ground troops finally did move forward, they faced a defeated enemy that surrendered by the tens of thousands virtually without a fight.

Finally, airpower had fulfilled the promises its advocates had been making for decades. But curiously, in studying airpower, talking to its practitioners, and teaching it to junior and mid-level officers, as I have for 27 years, I have found airmen unable to articulate their success story effectively. Why?

> Until airmen can measure their technology's effectiveness, airpower will remain as much a promise as it is a solution.

One recurring challenge to airmen that turned up during the Gulf war is the inability to definitively measure the effects of air attack at the strategic level. Measurement at the tactical level has not been difficult: When a bomb strikes a tank and blows its turret off, there is no disagreement about the attack's effect. But when a bomb hits a power transformer and shuts off electricity to an area, the effect of that blackout—although recognized as significant—is not so obvious.

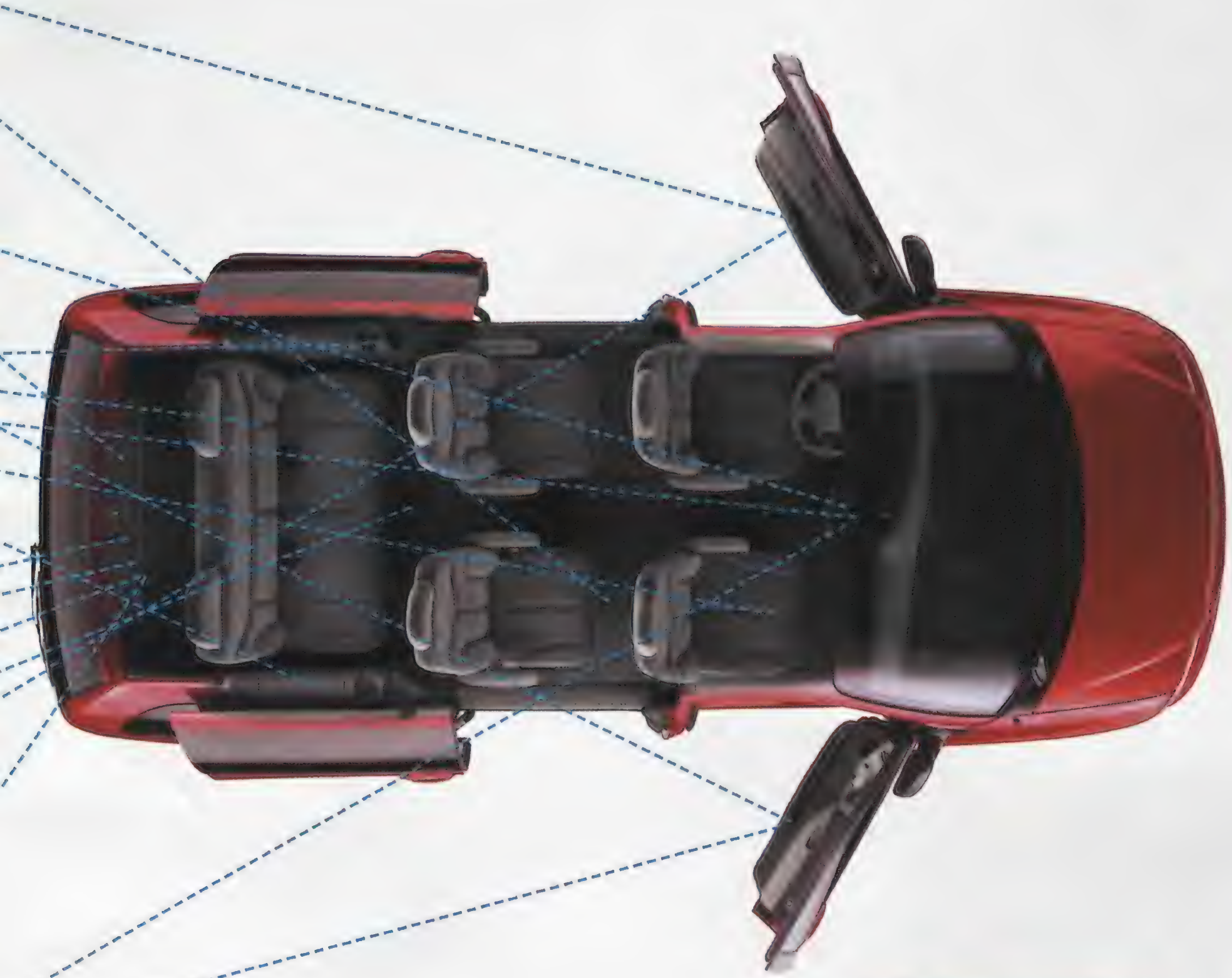
The inability to measure strategic effects is the greatest challenge facing airmen today, because until that is possible, it is difficult to articulate airpower's uniqueness and importance. That, along with a fear of again being accused of overselling the abilities of their instrument, has made airmen reticent to define their record in war and to promote their cause. This issue has a technological dimension: Computer war simulations, for example, must be made to more adequately illustrate the cascading effects of a crippled communications net or transportation system. However, the challenge is predominantly an intellectual and conceptual one. To overcome it, airmen must study airpower, analyze it, recognize its strengths and its weaknesses, and explore new ideas. They must understand what they are trying to achieve and how to determine whether they have achieved it. Until that occurs, airpower will remain as much a promise as it is a solution.

Regrettably, it has become conventional wisdom to call the Gulf war an anomaly—the last of the old wars—and to see future war as being of "low intensity," meaning that unconventional forces, guerrillas, terrorists, and drug lords will dominate future conflicts.

Accepting such a prophecy would be extremely risky. After all, many pundits were saying precisely the same thing *before* the Gulf war. Regardless of the level of future conflict, war will remain essentially what it has always been: the necessary use of force against an enemy. And airpower remains the weapon that can apply that force at a greater distance, more rapidly, more precisely, and with less risk. All the services understand this, hence the enormous sums spent on aircraft carriers and air wings, cruise missiles, attack helicopters, and unmanned air vehicles. The disagreement comes in how best to use airpower.

The author, a colonel in the U.S. Air Force, is a command pilot who has served in the Pentagon and as dean of the School of Advanced Airpower Studies.

You've got to hand it to our engineers in the compartment department.



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HOVER

"Ladies and gentlemen, boys and girls! At this time I am proud to present the United States Army Helicopter Square Dance Team: two lovely ladies, Harriet and Henrietta, and two gents, who are Hank and Henry. Let's give them a big welcome by waving your hands or handkerchiefs so they can see you!"

If that announcement didn't grab your attention, what happened next certainly would. Four Army helicopters would fly onto the field, painted in bright pastels and garish polka dots, wearing hats and wigs and skirts. After bowing to the crowd, they would face each other foursquare and perform an honest-to-God, chicken-in-the-breadpan square dance, while loudspeakers blared "Turkey in the Straw."

It was the 1950s. America was in bobby socks, the military was booming, and a new type of aircraft was on display. An unexpected star in evacuation and rescue on the battlefields of Korea, the helicopter was still a novelty across much of the country. "Most people had never seen an airplane do anything but take off and land in a straight line," says square dance team member Ned Gilliand. "This was a new flying machine that could hover, back up, go sideways, even spin on itself."

The show created by Gilliand and his

Anthropomorphic Bell H-13s do-si-doed up a storm at the hands of Ned Gilliand (opposite) and his Army teammates at 1950s airshows.

DANCE

It took a tough pilot to make a helicopter dance.

by Frank Kuznik

Photographs courtesy Ned Gilliand

colleagues ran intermittently, in various incarnations, for 25 years. This little slice of aviation history is memorialized in *Dancing Rotors*, a photo memoir that Gilliand compiled after he retired from Bell Helicopter in 1986. As the book shows, both the Navy and Marine Corps fielded helicopter demonstration teams during the 1950s, though neither was as elaborate as the Army's.

The helicopter square dance team was the result of a number of factors intersecting in the early 1950s at Fort Sill, Oklahoma, where the Army's rotary-wing pilot training program was under way. After being left in the dust when the Air Force went off on its own in 1947, taking most of the fixed-wing aircraft with it, the Army program was anxious to prove itself, and not shy about pushing the envelope—or, more accurately, creating the envelope. Helicopters were so new that many of their flight characteristics were still unknown.

"Every day was a learning experience," says team member Charlie Martin. He credits the commanding officer, General Carl Hutton, for setting the school's freewheeling tone. "Hutton gave us our heads to do what we wanted to do. If he hadn't, it would have taken a lot longer for helicopter flight techniques to evolve."

The training division geared up to sell the value of helicopters, both to the military establishment and to the American public. Army aviation was competing for a share of the military budget. "Different branches of the service are always trying to grab the hearts and pocketbooks of the American people, competing to have their latest toy," says

Jack Greene, an instructor and team member. "Even in the military at that time, there were many people who had never seen a helicopter, or maybe only a picture, and never actually saw one maneuvering."

Flight demonstrations got started at Fort Sill in the late 1940s. Since the routine consisted of five Bell H-13E Sioux helicopters making coordinated movements around the center and perimeter of a large square, it was natural that within a few years crews had turned them into dance steps—or a reasonable facsimile—and set them to music.

And square dancing was a natural in Oklahoma, where farming was the principal occupation and hoe-downs a popular social activity. "You were out in the middle of nowhere and there was not a whale of a lot to do," recalls Gilliand. "The farmers loved to have festivals, and the military participated. That's where I met my wife. Her father was a peanut and cotton farmer and a state champion fiddler."

Costumes were improvised for boy-girl partners. Initially, simple faces were painted on the inside of the bubbles, but the paint ran or smeared in the morning dew and humidity. Instead, the crews painted eyes, noses, and mouths on squares of oilcloth that could be taped in place. Over time, the costumes grew more elaborate, made from whatever materials were at hand: Floor mops became wigs, a helmet liner painted red and strapped on with parachute cord served as a nose, and colorful pan-

The team switched to the beefier Sikorsky H-19D in 1956, which offered more square footage for faces (above and right). But during one show the blade tips of two H-19s meshed, sending tip weights winging through the bleachers; after that, the H-13 was recalled to square dance service.

els of target cloth from the firing range (first soaked in fire-retardant liquid) were draped around the fuselage for skirts or wrapped around wire frames shaped like ears and bow ties. One problem with the costumes was trying to maintain visibility. "On certain maneuvers, when you dropped your nose to accelerate, all of sudden you were trying to look up through a hat or a wig," says Gilliand. "So you'd stick your head out the door, just like driving down a country road in a Model T with a muddy windshield."

This was not difficult in a Bell H-13, several models of which the team flew during its first five years. Other helicopters, like the Hiller H-23B, were rejected as too heavy or underpowered; the Sikorsky H-34A was deemed too noisy, drowning out the music and the caller, and also kicked up huge amounts of dust with its prodigious rotor downwash. The lightweight, maneuverable Bells, with their big bubbles and enough power to operate on hot days, were best suited to precision flying.

Local scribes were often colorful in their descriptions of the aircraft. One

reporter wrote: "The once new-looking army helicopters were now painted up as two rustic swains with wicked leers and two pert lasses with country-fresh smiles."

The team appointed a "caller," usually a backup pilot who chanted the dance verses:

Up the river and down the lake
Meet your own in a Ford V-8.
Hurry up now and don't be slow,
Swing that gal from Idaho.

The corn pone image, as far as the pilots are concerned, wasn't a slight to their skills or even incongruous with a military demeanor. "The narrator made a point of saying this was being done by very highly qualified Army aviators to show the versatility of the machine," says Gilliand. "They didn't say, 'Here's a bunch of pilots who are going to chase each other around with music and somebody hollering into a microphone.' "

"We had one general who thought this was not a very good image of Army aviation, so we got rid of him," says team member Clyde Emery. "You know, we were all warrant officers being greeted by four-star generals, mayors, editors of papers, and signing hundreds and hundreds of autographs. We were treated like celebrities, and it was a wonderful experience."

The most popular celebrity on the demonstration team was Bozo the Clown, a fifth H-13 with a flashy set of stunts. Bozo had his origins in the early demonstrations, when Charlie Martin found he could get a laugh by occasionally wandering off or making a wrong turn. He soon developed other tricks. "I'd go over to where the narrator was and blow all his papers away," Martin recalls. "Then maybe I'd find some gal who was kind of close to the end of the stands and lift her skirt with rotor wash."

When Greene took over in 1952, he developed it into a full-blown daredevil routine, throwing the helicopter into aerobatics both comical and dangerous. "They were maneuvers you should not be doing," he admits. "I pushed that thing right to the edge of the envelope and beyond. Sometimes I scared myself. But, you know, you were young and enthusiastic and thought you could fly any damned thing in the world."

Later Bozos focused more on stunt work: tipping over a 55-gallon drum and blowing it around with rotor wash, picking up big rings on the toes of the skids and twirling them, and playing with a yo-yo. A scaled-up model of the common toy, the yo-yo weighed about 70 pounds and was as tricky to operate as the real thing. If the pilot didn't catch it at the right moment on the downspin, it would jerk the helicopter down, or whack the skid coming back up.

"There was quite a learning curve," says Gilliand. "Seven times up and down is the most anyone ever did. If you could do it twice in front of a crowd, they were happy as mud."

The smoothness of the routines belied their difficulty. Only instructor pilots were recruited for the original team because only they had the requisite hours and experience in the new machines. "You develop a tremendous reaction time flying with students—the old saying is: They try to kill you every 30 seconds," says Emery. There was no time to look at the instrument panel; pilots had to be focused on maintaining rotor clearances between helicopters, and symmetrical distances and height. Mostly, they flew by ear. "The transmission sat right behind you, and those gears sing at the right operating speed," says Gilliand. "A good pilot knows that sound like a musician knows middle C."

It was tricky flying the new machines, let alone doing close-quarter maneuvers. Fixed-wing pilots making the transition to helicopters had to unlearn the critical importance of airspeed and fight the feeling they were going to fall out of the sky at slow speeds or a hover. Learning to hover was a trick in itself, a function of balancing stick and rudder with a third control called the collective, which adjusts the "bite" or inclination of the blades to provide lift. And this was well before helicopters gained the luxury of turbine engines, so pilots also had to coordinate the collective and throttle, which was operated by twisting the collective lever in a manner similar to most motorcycle throttles. The piston engines were very responsive to the throttle, but it took practice to pull up on the collective to lift off the ground while rolling in throttle smoothly and not shooting past the engine's overspeed limits.

"One of the hardest things to teach people was just to hover and hold the helicopter dead still," says Gilliand. "Usually, the first hour on all three controls, they were all over a three-acre field. Then *bang*, it would come to them, just like that. Some guys never got it. You were given eight hours, and if you couldn't solo by then, you got kicked out" of the training program.

The clown-and-dance show was a hit, propelling the square dance team out of Fort Sill and into airshows and festivals across the country. "It seemed every time I turned around in 1953, we were packing our bags for another show," says Greene. This suited the Army's needs perfectly. The helicopter

demonstration team not only made a strong case for the new aircraft, it served as a recruiting tool for new pilots, which the Army badly needed.

The team traveled like barnstormers, flying in short hops to their destination, sometimes stopping at roadside gas stations to refuel. (Conoco and Shell only: their high-test fuel had an additive that kept the sparkplugs from fouling too quickly.) "We'd land at a filling station, shut down, lower the landing wheels, pull over to the pumps, and fill it up," says team member Fred Bell. "Of course, this always attracted a lot of attention. There would be pictures in the paper the next day and such."

"If we were going to stay in a town overnight, we made it a point to fly down the main street and circle around before heading out to the airport, which drew mobs of people," says Emery. "One time we stopped in a small town in Virginia where the mayor and the editor of the paper asked us if we would put on a show for them. We had permission to do that sort of thing, so we said, 'Sure, we'll do it tomorrow morning if you can get publicity out.' They said, 'Don't worry about that.' We wound up staying there three days."

Life on the road was a blast. "We would buzz cattle, and when we saw people out in the farm fields, we'd give them a little buzz job," says Bell. One time the group spotted a young girl heading from a rural schoolhouse to the outhouse. "The five of us went down and surrounded the building, slowly pivoting around it," recalls Gilliand. "The door cracked open and you could see these eyes peep out. This gal had probably never seen a helicopter in her life before. She came running out with her britches half up, and we started herding her toward the school. All of a sudden the school door opened and out came a guy with a shotgun. We just scattered."

All business at the shows, the square dance team would perform a seven-minute routine (which eventually grew to 15 minutes) of paired twirls and pivots, tight circles, and close passes. The key was a set of markers—cloth panels staked to the ground in a five-spot die pattern, 90 feet from corner to corner. The helicopters started at the corners, with the panels positioned precisely between the pilot's feet, then followed the lead pilot's commands to execute and break each maneuver.

None of the pilots could hear the music. "Frankly, I didn't have the slightest idea what square dancing was," Greene confesses. "We performed by [radio] command." But the maneuvers had been worked out in time to the music, and a good caller, clapping and pumping the crowd, could make it all seem in synch.

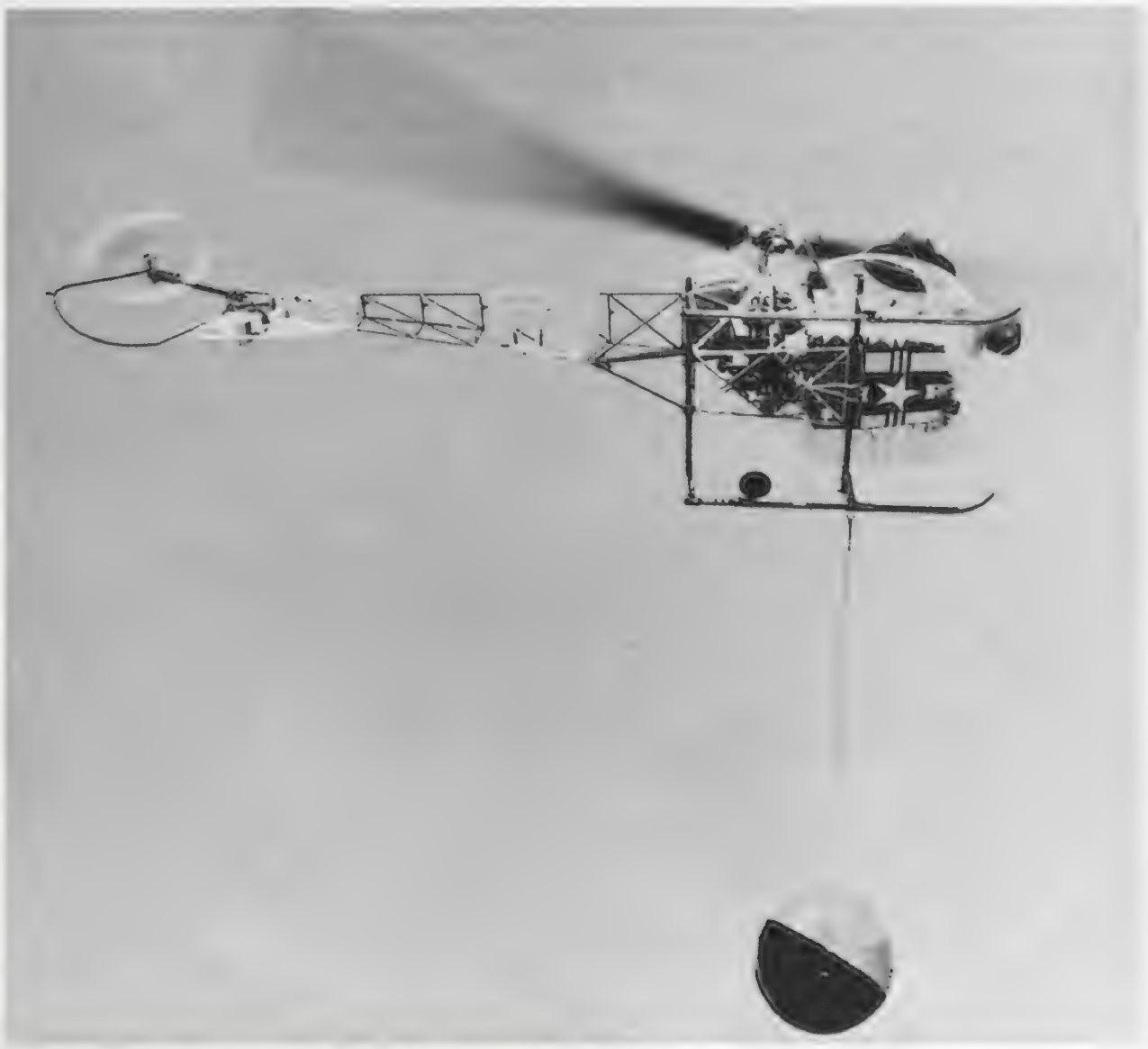
The team was practically in the audiences' laps, maneuvering about 150 feet from the grandstand and a mere 25 feet off the ground. "Not to disparage the Blue Angels or Thunderbirds, but you didn't have to look around in the sky for us—we were right there in front of you," says Bell. "A lot of people didn't know a square dance from a waltz. But we were dressed up crazy, doing these weird, intricate maneuvers, and it fascinated them."

The first team had two accidents, but none during a performance. One occurred when two of the H-19s were taxiing to park after a practice at Fort Rucker in Alabama in 1957 and Bell misjudged his rotor clearance by an inch or two, nicking his blades against his partner's and sending blade tip weights flying through the bleachers. "All they had to replace was my rotor blades," says Bell. "I say that's all—actually, it was quite costly. But I was never charged with an accident. It was accepted as part of the demonstration hazard."

The other accident happened during dress rehearsal for the 1956 National Aircraft Show in Oklahoma City, a milestone of sorts for the team. With other demonstration groups graduating to higher-performance aircraft, the square dance pilots had been given their choice of new aircraft. They settled on the Sikorsky H-19D Chickasaw, a brute nearly twice the size of the H-13, with acres of space to decorate. Gilliand designed the new paint jobs and went whole hog. The "women" were given bright bows and polka dots. The "men" got pockets holding a comb or whiskey bottle, plus new props—corncob pipes (painted aluminum stovepipe) and Li'l Abner-style boots made of plywood.

The rehearsal was held at Fort Sill

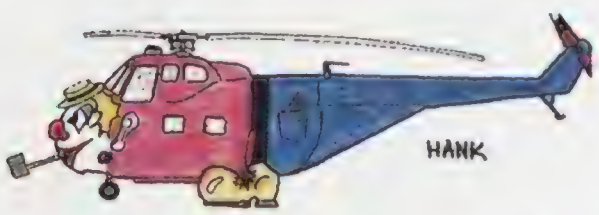
The yo-yo routine called for a lot of practice; seven times up and down is the record. "If you could do it twice in front of a crowd, they were happy as mud," says Gilliand.

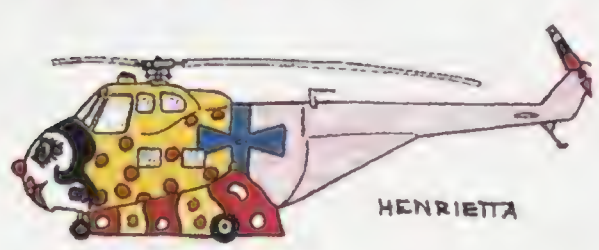


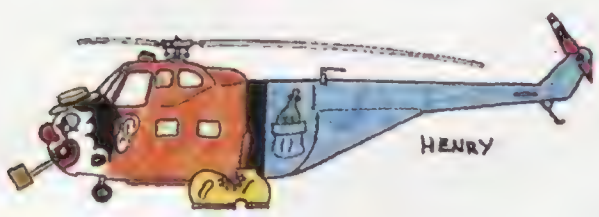
on a day so gusty the pilots were reluctant to fly. "But the colonel who was the director of the Army show insisted," says Emery. "I thought, *Oh boy, here we go*." The team planned to unveil a new maneuver, a backward takeoff and flight in diamond formation—a dainty move for the big Sikorskys. All went well until the pilots' radio frequency was jammed by another flier, and Emery, the right wingman, missed a course correction. When a gust of wind hit him, his tail rotor veered into the main blades of the rear H-19.

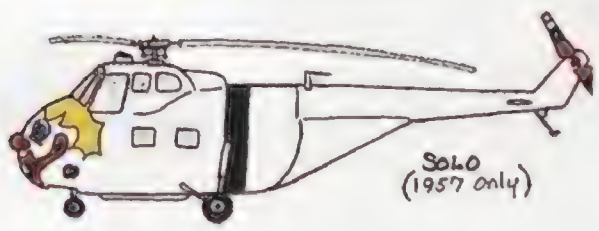
The rear man struggled with severe vibrations induced by bent and broken blade tips and fell in rearward flight, settling with a nose-down momentum that broke off the nosewheel assembly when he hit the ground. Emery, meanwhile, had lost his tail rotor, which caused the H-19 to instantly roll onto its right side and fall some 70 feet. Shortly after impact, he escaped through the copilot window and ran to safety. "It was a hairy experience," he recalls.

"Ladies and gentlemen, we bring you the modern version of the ancient sport of tilting at rings..."









When the team switched to the H-19s, add-ons like boots and corncob pipes got elaborate. All items were scrutinized prior to a performance: "It was enough of a task to be flying backward by your opposite without having to worry if an ear, hat, or skirt would come loose," says Gilliand, who sketched the paint schemes and costumes for the team's new dancers.

Neither pilot was injured, but their helicopters were trashed. High-ranking officers intervened, telling the team to find two replacement H-19s from the many assembled at the base. One was a brand-new Sikorsky that had just been flown up from Fort Hood in Texas. "The pilot of that helicopter screamed like a mashed cat," recalls Bell, "because we stripped everything out of it and turned a beautiful new paint job into these horrible pastel colors. Our colonel said, 'That's too bad, but we're going to have a team.' " The pilots recruited volunteer help and stayed up all night painting and outfitting the new aircraft. By morning, the square dance team was ready to fly again. But from then on, the H-19s were grounded when winds exceeded 28 mph.

The team performed for huge crowds in Oklahoma City, putting on three "perfect shows," according to Gilliand—less the backward diamond, which was never flown again. Igor Sikorsky was in the stands and was reportedly thrilled by the dexterous performance the pilots wrung out of his bulky H-19s. "The military people I knew who sat with him said he was ecstatic," says Bell. "He couldn't believe his helicopters were doing that."

The helicopter demonstration team dazzled airshow audiences for another five years before shifting priorities and budget constraints shut it down in 1961. By the time it was revived in 1972, the image and role of the helicopter had changed radically, particularly after its media exposure during the Vietnam war. The routine had changed too; instead of square dancing, seven Hughes OH-6A Cayuse helicopters did flashier maneuvers and shot off trails of white and red smoke. The team, now called the Silver Eagles, gave over 220 performances before being disbanded in late 1976.

In the 1950s, flying with the demonstration team had been a badge of achievement. That changed in the 1970s as well. "There were people who were asked to join the Silver Eagles who refused because they were afraid it would hurt their career," says Gilliand. "I talked to one pilot who was on the team for a while but got out of it as quickly as he could because he was afraid the dancing-helicopter tag would hurt his chances for advancement."

Maybe people took things less seriously in the 1950s, or maybe, with the threat of nuclear Armageddon lurking, they were simply more grateful for distractions. Even the military airshows of the time could be pretty scary. Just the Army portion of a typical show in 1955 featured 20 displays of troop and artillery deployments and concluded with a simulated atomic bomb explosion. At shows devoted to the serious business of proving U.S. military readiness, dancing helicopters struck a much-needed light note.

ORDEM E PROGRESSO
BRASIL
Alcântara
São Luís
SELVAS
BRAZIL
CHAPADA DE MATO GROSSO
SERRA DO RONCADOR
MATO GROSSO DO SUL
Brasília
Campo Grande
Uberlândia
Uberaba
São Paulo
São Vicente
PORTO ALEGRE

Welcome to the Club

After a 30-year struggle, Brazil is poised for a place in space.

by Carl Posey

Illustrations by David Peters

Just over two degrees south of the equator on Brazil's northeast coast, Alcântara has existed since European time began in the New World. It enjoyed perhaps a century of wealth from exports of cotton, then rubber, but now there are just low, moss-colored headlands and emerald jungle, a rough wooden wharf, a cheerfully squalid town of pastel stuccoed mud brick perched among colonial ruins, and pigs foraging in the muddy streets. Aside from the occasional tourist—the entire town is an architectural landmark—the world largely turned away from Alcântara.

Now the world is back. About 7:30 every weekday morning, an 85-foot launch from São Luis, an island city across São Marcos Bay, pulls up at the dock and about a hundred people disembark, most of them in the livery of the Brazilian air force—some wear blue shirts and full insignia, but the majority, in a concession to the steady, humid heat of the place, favor white T-shirts stenciled with name, rank, and a bit of heraldry: the insignia of the Centro de Lançamento de Alcântara, or CLA—the Alcântara Launch Center.

To this almost forgotten corner of the planet, Brazil has deployed about 600 people, half of them civilians, with a daunting mission. They must boost their huge, volatile, still-evolving country into the elite ranks of spacefaring nations—a club whose members are capable of building and routinely launching rockets that can place satellites in Earth orbit.

The achievement would be remarkable in itself—in the developing world, China and India are the only others to have qualified. But perhaps the most remarkable quality of the mission at Alcântara is its age. Many of the men and women now boarding blue air force buses weren't born when Brazil began its long march toward space in the 1960s. The journey continued into the 1970s and the days of *Brasil Grande*—Great Brazil—when a sanguine military government, caught up in the boomtown spirit of the times, sought national greatness by building the biggest, longest, or most complicated everything. In Brazil's nascent space program, expansiveness took the form of the Brazilian Complete Space Mission, which in 1979 articulated three objectives. It would develop indigenous satellites, produce a Veículo Lançador de Satélites, or VLS, to place them in low-Earth orbit, and construct a major launch facility for the VLS at Alcântara.

Geography made this a near-perfect site. Alcântara's field of fire is a yawning V of more than 107 degrees, permitting trajectories over the Atlantic Ocean from a bit west of north to due east. The site lies almost on the equator, adding the strongest possible impetus of Earth's eastward rotation. This extra bounce translates into fuel savings of 20 to 30 percent, compared to the fuel needed at such higher-latitude sites as Florida's Kennedy Space Center and California's Vandenberg Air Force Base, and weight saved in fuel can be carried as payload.

For the launch center, the Brazilian Air Force expropriated 24 square miles of a peninsula that had been scrub brush and a scattering of farms, and poured some $230 million into buildings and roads. Meanwhile, more than a thousand miles to the south, scientists and technicians were learning to build and operate satellites. All they needed was a Brazilian booster to validate the nation's spacefaring credentials—and turn a profit.

Work had begun on that goal in 1965, with the small Sonda I

sounding rocket; more than 200 launches were carried out over 12 years. Soon after Sonda I began, Sonda II was under way to test improved propellants, aerodynamics, electronics, and thermal protection. A two-stage rocket, Sonda III, flew in 1976.

Sonda IV, with a Sonda III as a second stage, had four successful launches between 1984 and 1989. Despite such progress, by 1991, when the first Brazilian satellite was ready, no Brazilian booster was waiting for it. The Satelite de Coleta de Dados (Data Collection Satellite) SCD-1 was placed in near-circular polar orbit in 1993 by a U.S. company—Orbital Sciences Corporation—using a B-52-launched Pegasus booster. Brazil paid OSC $14 million for the launch.

The Brazilian satellite launch vehicle that a decade earlier had seemed to be just around the corner had somehow failed to materialize. In fact, in the austral autumn of 1997, while three more SCDs languished in a clean room hundreds of miles away, the only launch on view at Alcântara was the one that arrived every weekday morning from São Luis.

Our minder at Alcântara is Luiz Alberto de Almeida e Silva, a puckish air force major and engineer attached to the operations division at CLA. Almeida comes from Brazil's deep south, the son of a three-star army general. Like most of his colleagues, he has spent a good portion of his career learning the space trade in the United States and Europe and alongside the French rocketeers at Kourou in French Guiana, where an Ariane rocket is launched almost every month. His Brazilian tours of duty include one at the Barreira do Inferno "Wall of Hell" range, near Natal, where the military tests artillery and air-to-air missiles and where that same military proved the Sonda rockets.

Like all Brazilian air force officers, Almeida wears wings, but not those worn by aviators. His is the engineer insignia: a missile against the symbol for the atom, a set of electron orbits. When asked about the nuclear reference, Almeida shrugs it off. "An accident of design," he says. "I think it is an artifact of the cold war."

The insignia dates from the post-World War II years, when piling up arsenals of nuke-tipped ballistic missiles seemed affordable and strategically sound. And it helps explain why Brazil has had spacefaring competence within its reach for so long, without being able—or allowed—to grasp it. The major's insignia evokes what the policymakers of the more developed nations see when they look south—fossil traces of an unstable military past, a perception that has had grave consequences for Brazil's space program. For as the Sonda rockets progressed, an odd thing happened. To the watching world, Son-

das I through III had looked like sounding rockets; Sonda IV looked like an intermediate-range ballistic missile, and it triggered alarms in the world's nonproliferation community.

Since World War II, the industrial powers have tried through various treaties and alliances to inhibit the spread of dangerous technical knowledge—the means of building nuclear, chemical, and biological weapons of mass destruction and deploying them on missiles. Such agreements have always divided the world in two: on one side, the vastly more numerous have-not nations who resent the restraints on their development; on the other, the richly armed nations that give the pacts their teeth and believe they are keeping destructive powers from unreliable hands. Those attitudes hardened long ago, before anyone besides Jules Verne had much interest in large rockets.

In the years leading up to World War I, the great powers in Europe engaged in an arms race of unprecedented magnitude involving giant battleships. The naval rivalry between Britain and Germany traveled across the waters to South America, igniting an unlikely arms race among Chile, Argentina, and Brazil, none of which had the slightest interest in fighting but all of which had a powerful interest in national prestige. From British shipyards Brazil bought *Minas Geraes* and *São Paulo*, which outgunned anything else in Latin America, guaranteeing further escalations. And the super dreadnought *Rio de Janeiro*—familiarly, the Big Battleship—was the largest and most heavily armed vessel constructed by anyone, anywhere, ever. But Brazil was unable to sustain the expense, and the *Rio* spent its service life in the British royal navy as HMS *Agincourt*.

The spirit of such episodes still haunts modern arms sales. The United States dithered over selling F-16s to Chile, for example, because, in the northern view, such jets might have sparked another prestige-powered arms race. How Brazil's emerging space effort would affect the neighborhood was also a concern, especially because Argentina was suspected of having what

Geography made this a near-perfect launch site, with a field of fire over the Atlantic of more than 107 degrees.

those who study nonproliferation issues call a "Parallel Program"—efforts to create both a nuclear bomb and a ballistic missile.

As early as 1972, a jittery United States had banned the export of satellite launch vehicle technology and established a process of reviewing relevant export requests. The jitters persisted as South Korea tested a ballistic missile in 1978 and Iraq tried to buy Italy's retired rockets in 1979. India launched its SLV-3, another satellite launch vehicle that had begun to look a bit too muscular, in 1980. Germany's OTRAC tested a rocket in Libya in 1981. In South America, Argentina had established a bi-national company with Egypt, reportedly funded by Iraq, to build the Condor II medium-range ballistic missile, a mobile, multi-warhead weapon that a Patriot missile, for example, would have been unable to engage.

And then there was Brazil, huge and ambitious, ruled by a series of military dictators from 1964 until 1985, with the now alarming Sonda and VLS programs administered by the military. During the 1980s, Brazil's aerospace giants, Avibras and Embraer, made it known that they'd discerned a latent ballistic missile in Sonda technology, and began talking up the export possibilities. "They got a lot of publicity in the 1980s," recalls one observer. "A burden they are still carrying around."

From the outside at least it seemed as if Brazil's spacefaring impulse had sent the world's fifth-largest nation wandering into the company of such rogues as Iraq, Iran, North Korea, Libya, and, closer to home, Argentina. A 1987 Congressional Research Service report named Iraq and Libya as Brazil's potential clients. "Some reports even claimed that [prior to the 1991 Gulf war] Iraq shipped a Scud missile to Brazil where Avibras replicated the missile's components in order to provide replacement parts to the Iraqi military," according to a 1994 analysis published by the Center for Nonproliferation Studies in Monterey, California. Even with the end of its military government in 1985 and the adoption of a new constitution in 1988, Brazil found itself tarred with the arms merchants' brush—and out of luck, as far as furthering the VLS was concerned.

For, while Brazil dabbled in the Middle Eastern arms bazaar, the Reagan administration was closing the door on the means of making missiles. By April 1987, the United States, Britain, France, West Germany, Italy, Canada, and Japan had adopted guidelines for the Missile Technology Control

Regime, or MTCR. The member nations agreed not to export equipment and technology that other countries could use to make delivery systems for nuclear weapons (see "Members Only," p. 63). And, just like that, the door slammed shut.

The alliance changed the world for rocketeers. Italy, under pressure, ceased supplying missile technology to Argentina's Condor II project. Germany, criticized for its role in the same program, improved export controls. In 1989, after U.S. protests, France withdrew its offer to send Arianespace Viking liquid-fueled rocket technology—and a team of experts—to Brazil. A French proposal to sell cryogenic engine technology to India likewise brought a U.S. threat of economic sanctions and was tabled. By May of 1991, the Condor II was dead.

The MTCR wreaked havoc in Brazil, where it was seen—and is still seen—as a gratuitous slap at a pal. "The MTCR changed the quality of our cooperation with the United States," observes one Brazilian diplomat. Within the MTCR's first year, the Brazilian air force announced that it would be unable to complete the VLS before 1992 because of this technological blockade.

Some experts still believe the MTCR was all that stopped Brazil from building and exporting ballistic missiles cloned from the Sondas and the VLS. But leaders of the Brazilian space program make a pretty credible case that there never was a missile—that the notion, like the winged rocket and Bohr atom on Almeida's uniform, was an artifact of another time, an element of mythology.

"Of course, there is a certain amount of truth in all those myths." The speaker is Luiz Gylvan Meira Filho, the president of Brazil's space agency—Agência Espacial Brasileira, or AEB. A lanky, scholarly man, Gylvan speaks slowly and precisely as he consumes cigarettes and demitasses of thick, black Brazilian coffee. His office is in one of the tired-looking government high-rises composing the skyline of the capital, Brasília.

"It is true," Gylvan resumes, "that conceptually a number of years ago Brazil considered possible export. It would be only something to look at. We had military-dominated governments for a number of years. Some were very good, as a matter of fact. Some were not. And because the Brazilian Commission for Space Activities was under the joint chiefs, it is true there was a certain mixing between the military programs and the development of sounding rockets, or the VLS. Having said that, I repeat that we never had a program to build ballistic missiles."

"It is true there was a mixing between the military and the development of sounding rockets," says Gylvan. "I repeat that we never had a program to build ballistic missiles."

Gylvan's agency owes its existence to Brazil's decision to carry that argument to the rest of the world. Established in February 1994, the AEB assumed the functions of the Commission for Space Activities, effectively moving the program from military to civilian hands. At the same time, Brazil said it would abide by the MTCR guidelines.

Responding to such signals, the United States let Brazil see what was available to members of the MTCR. In 1994, NASA joined forces with Brazil's space research institute in the Guará campaign, which launched 30 sounding rockets—mostly Nikes and Black Brants—from Alcântara, "bringing CLA," as one Brazilian publication put it somewhat extravagantly, "into line with some of the more advanced launch centers in the world." According to one NASA participant, the experiment was also a carrot to lure Brazil aboard the MTCR. A year later, in a controversial move, the Clinton administration waived its objections to Russia's sharing with Brazil the technology for making strong, light graphite-fiber motor casings.

One way to explain why the policy toward Brazil relaxed is that the United States recognized a crucial difference between Brazil and the so-called rogue nations: Brazil was not building The Bomb. Although it once reached the technical threshold of being able to develop nuclear weapons—its national Institute for Energy and Nuclear Research, for example, was working on a uranium enrichment facility—Brazil had since put its nuclear programs under international safeguards and entered a bilateral nuclear nonproliferation pact with Argentina. In October 1995, six days after the Brazilian senate enacted a bill that imposed export controls on launch materials, MTCR members voted to accept Brazil into the regime. Membership was approved on the condition that the 1980s missile

projects had been terminated.

"Brazil was kind of a unique case for us—the only country to come into the MTCR with a VLS in its pocket," an American expert explains. "We could have said 'You have to give up everything,' but that wasn't sustainable. We could have said 'We don't care what you have when you enter.' We drew a line in the middle. We knew the VLS was capable of being used as a missile. We're saying that if the government has said it will not use that technology militarily, no weapons of mass destruction, and good controls, it mitigates the risk of the VLS."

Gylvan elaborates a little on the changes in Brazil that affected its trading status. "It was not simply that we made a deal to join the MTCR," he says. "My perception is that there was a major policy shift in Brazil. It took a number of years, changes in legislation, a change in the culture." Once new legislation was in hand, he explains, the government took a second crucial step: it removed policy-making from the military. "We are the only agency which is by law a civilian agency," Gylvan points out. And finally there was the matter of stating explicitly that Brazil would not produce ballistic missiles. "The point was made extremely clear in a major policy speech: We aren't and we won't." Having genuflected, or, as Gylvan put it, experienced a profound policy change, Brazil could buy anything it wanted for its own use. The VLS program quickly regained its vitality.

"We are doing four prototypes," says Gylvan. "In parallel there are preliminary talks about the VLS-2 system"—an advanced booster with a liquid rocket in an upper stage, capable of putting a couple of tons in a 2,000-kilometer (1,250-mile) orbit.

But why do it at all?

An American observer replies: "Mostly a prestige thing—'we're serious players, we launch our own satellites.' " In other words, the space program is the Big Battleship, writ modern.

Gylvan chuckles at this. "Some guys in Washington think they should treat South America the way they treat Mexico. But we are much farther away." Gylvan agrees that the desire for national prestige motivated past regimes, but he says, "It's not the case in the present government. Prestige doesn't sell politically. If I go in and say 'I'll give you prestige for a billion dollars,' they'd throw me out. You very clearly need a justification. That's why the first chapter is applications." Earth observation and communications satellites cost millions to develop, but in the long run they cost more to buy. And a legislature is much more likely to appropriate funds to a program that can promise a return by selling satellites and launch services and that can nurture related computer and electronics industries.

Down the hall in the Brasília tower, Gylvan's director-general, Ajax Barros de Melo, echoes the emphasis on programs that make economic as well as technical sense. A compact, wise-looking man, he is referred to throughout the AEB as the Brigadier, his pre-retirement air force rank. In his view, Brazil can become an active—as distinct from a symbolic—spacefaring nation only by finding a sphere of influence, a market, a niche.

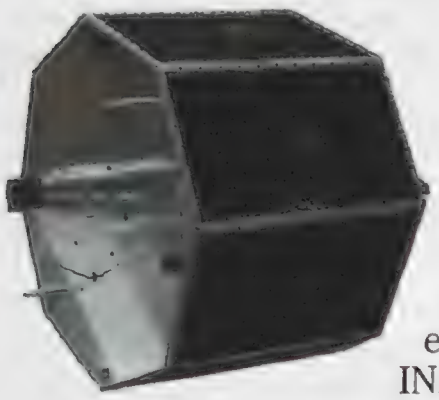
What he and many of his colleagues conjure is a world that is neither eastern nor western, northern nor southern, but equatorial. Barros de Melo muses about finding markets for space program products among the growing population and wealth of the geographical band between the tropics of Cancer and Capricorn, a waterworld that is, coincidentally, also the Third World. Look at that tropical region as a strip around the globe and in it you see only one giant, one evolving superpower, among the developing host—Brazil.

The space-related offerings Brazil takes to that equatorial world will come from the Instituto Nacional de Pesquisas Espaciais—the National Space Research Institute. INPE's airy, open buildings are located on a eucalyptus-lined campus in São José dos Campos, a kind of middle-tech Silicon Valley city about 60 miles northeast of São Paulo.

INPE has about 1,300 employees on this campus, 400 of whom hold doctoral degrees; they stroll about the place dressed with the informality of graduate students. INPE boasts, among other things, the Integration and Test Laboratory, the only facility of its type in the southern hemisphere. Here, both the small Brazilian-built SCD satellites and the big Brasilsat telecommunications satellites, built by Hughes and launched by Ariane rockets, are assembled and tested. Another facility down the road handles computer applications and satellite imagery and houses Brazil's new supercomputer-equipped Weather Prediction and Climate Studies Center.

Marcio Nogueira Barbosa, the urbane mechanical engineer who has directed INPE since 1989, trained in Canada and in the United States with NASA, specializing in remote sensing—he is current president of the International Society of Remote Sensing—and, like many of Brazil's technical cadre in the space program, worked as a young engineer in France. "I was invited to join INPE in 1972 to do a

master's program here," he says. "That explains why I am here so many years." The idea was to begin developing scientists in São José dos Campos, then send them abroad to earn their Ph.D.'s. "We can today be considered successful because we have 400 guys who are qualified, and every year I send 50 guys out to Europe and the U.S. Everybody in a key position had a chance to be abroad."



As this pool of talent evolved, INPE turned to the uses of satellite information. "Brazil is a big country with a lot of natural resources, areas of difficult access, areas of defense, a long coastline," Barbosa says. "We need to get data and to communicate, provide products, to follow the natural situation. Monaco doesn't have this problem."

Brazil relies on satellites possibly more than any other nation. With few roads and relatively undeveloped telecommunications in the country, satellites have been used for collecting information about weather, water levels, and rainforest burning in order to make decisions affecting agriculture and hydropower. Law enforcement agencies have used remote sensing data to find tiny scars in forestland that pinpoint jungle landing strips carved out by illegal drug traffickers.

Having demonstrated the utility of such products, INPE turned to designing its own satellites. The first were based on 1960s-vintage types resembling the early TIROS (Television and Infrared Observation Satellite) hatbox. "The initial family was for forest monitoring," Barbosa says. "One to collect environmental data. Platforms three and four were remote sensing." The SCDs gather and relay data from hundreds of ground stations sprinkled across Brazil. With the advent of the MTCR, "we had to develop our own technology. Finally, in 1991, we finished the first satellite." That was SCD-1, launched in 1993 by Orbital Sciences' Pegasus. "Now we have three data collection satellites ready in the lab." SCD-2A, scheduled to fly on VLS-1, waits in a clean room.

The MTCR had another and more profound effect on INPE's operations. "Probably provoked by the embargo," Barbosa says, "we signed an agreement with China for a family of remote-sensing satellites." The deal represents a huge commitment by Brazil, which is contributing a third of the money and technology needed by the Chinese Brazilian Earth Resources Satellite; the first of four is supposed to fly aboard a Long March booster in 1998, the second in 1999. The program offers China and Brazil 3,000-pound satellites with high-resolution, wide-field imagery in the visible and infrared bands of the spectrum—a technological quantum jump.

INPE has now begun to purchase engineering services from private industry and is also ready to sell its products on the world market. Says Barbosa: "We can offer satellites to the private sector. We are attracting interest from several countries—France, Germany, the U.S., Canada. Our budget is four times that of four years ago. We are experiencing a good momentum."

The VLS series being developed by a sister agency is part of that momentum, but not all of it by any means. "If all goes well with the VLS demonstration, we have something that could complement other programs," says Barbosa. "Some things others aren't doing.

We need to monitor the Atlantic. We have a third of the world's forests. Why not do it? We want to." Why not launch an Earth-resources satellite into a low (600-mile) equatorial orbit instead of the usual polar orbit? It would give Brazil and other users in the tropical waterworld local images every hour and a half.

Mainly, Barbosa sees a space program that, despite some formidable obstacles, has finally come of age. "One important aspect of our current situation is the maturity we have achieved," he says. "At least two consortiums are being formed between Brazilian firms and foreign countries. Never happened before." He grins broadly. "We want to be part of the space station," he says. "I predict a Brazilian astronaut before the end of the century." Five years ago this would have been nothing but an attention-grabbing sound bite; now it may be a serious prediction. AEB and NASA are discussing potential roles for Brazil in the international partnership to build a space station.

Like a tangled vine in the rainforest rising toward the light, Brazil's space program may seem to be a bundle of unconnected strands. In fact, it is a single braid, grown from one deep root planted in the technologically fertile soil of São José dos Campos half a century ago. Separated by a high, guarded fence from the rest of the world, the Centro Técnico Aeroespacial—CTA—sprawls on a manicured site, where since 1950 it has provided the talent and technology that have begun to bloom in the first VLS. Luiz Gylvan trained as an electronic engineer here, as did Ajax Barros de Melo, as did Alcântara's Major Almeida, as did the various fathers and uncles of Brazilian as-

trophysics. From the beginning, all of Brazil's roads to space have led to, and from, this center of excellence, Brazil's MIT, Livermore Lab, National Transportation Safety Board, and Federal Aviation Administration.

Major-Brigadeiro do Ar Reginaldo dos Santos, CTA director since 1995, occupies a large, comfortable office cluttered with museum-quality models of airplanes, rockets, and satellites. "Most space activities started here," he says. A trim, businesslike administrator, he exudes the matter-of-fact confidence of an airline captain. He graduated from what is now the air force academy in Rio in 1962, then spent a year flying Douglas B-26 Invaders out of Natal. After earning his degree in electronic engineering in 1970, he spent seven years in the United States, studying bio-optics at Purdue. He was head of CTA's space research institute and its laser division.

Before the MTCR embargo began, dos Santos recalls, "we were talking with the whole world. We weren't interested in developing. We were buying. After that we had to use our imaginations and develop the whole thing here in this country."

Well, perhaps not the whole thing. In May 1995, *O Estado de São Paulo*, one of the country's major newspapers, quoted air force colonel Thiago Ribeiro, the Air Ministry's VLS manager, to the effect that Brazil had been able to solve only part of its guidance problem with local software makers. "We were forced to obtain some parts from the international black market. We bought the technology from Russia, France, Italy, and Germany," Ribeiro reportedly told the newspaper. "We even bought parts from the USA, despite the embargo."

The black market buys no doubt helped, but they fell far short of giving Brazil all it needed. "We couldn't buy things like gyroscopes, inertial platforms," recalls AEB's Barros de Melo. And Brazil had no liquid-fueled rocket experience. With the French offer of Viking technology quashed, they had to use what they had. "We had already some capability in solid propellant," dos Santos says. "So the first step was to do solids. At that time, they were used most by the military. People said solids had no future in space. We think we did the right thing. A small rocket for small satellites."

Last May six plump sausages of solid propellant wrapped in thin-walled steel cocoons lay in shipping pallets on the concrete floor of Alcântara's motor assembly building. All were about three feet in diameter. Five were about 12 feet long—the four strap-ons of the VLS-1 first stage and the central motor of the second stage—and contained 15,708 pounds each of hydroxy-terminated polybutadiene binder densely seeded with aluminum powder and ammonium perchlorate; the load was perforated with a star-shaped core. The sixth motor, about seven feet long, was the third stage. The fourth stage, also three feet in diameter but only three feet long, was moved north several months later along with the launch vehicle's steerable nozzles, guidance package, and other astronautical finery. All of the motors had been successfully static-fired down at CTA.

These middle-size rocket engines—they are about the same diameter, but nowhere near the length, of the strap-on solids boosting the U.S. Delta II—are presided over by Luis Carlos Bruno dos Santos, a cheerful, mustached man in a white CLA T-shirt; he holds the equivalent rank of master sergeant. In a sense, he is the keeper of the central elements of a technological miracle: The engines are made in Brazil.

One of the many myths that swirl around the VLS project is that Brazil could not have attained success with

Members Only

The six nations that joined the United States in the Missile Technology Control Regime in 1987 in effect adopted U.S. export restrictions. The United States has been the most vigorous enforcer of the guidelines and in 1993 broadened them to cover potential missile delivery systems for chemical and biological weapons as well as nuclear. Today 28 countries belong to the MTCR.

The agreement identifies 20 groups of items in two categories: Category 1 items are complete missile systems and subsystems and related production equipment; category 2 comprises less-sensitive "dual use" technologies that have applications other than as components of weapons. They include rocket motor casings, separation mechanisms for rocket stages, liquid and slurry propellants, avionics equipment that could be used in rocket launches—for example, radar systems and GPS or similar satellite receivers—and test facilities, such as wind tunnels for speeds of Mach 0.9 or more.

For both categories, the critical performance parameters are a range of 300 kilometers (186 miles) or more and a payload of 500 kilos (1,100 lbs.) or better. The numbers came from a Canadian estimate that infant nuclear states will probably deploy cumbersome warheads and the fact that ranges in such potential theaters of conflict as the Middle East can be quite small. Unlike the nuclear nonproliferation treaty, the MTCR offers no quid pro quo of any kind—adherence does not confer a right to receive such technology, and U.S. policy continues to be one of not encouraging satellite launch vehicle programs in other countries, period.

Because it lacks treaty status, the MTCR has no real teeth other than the threat of trade sanctions, which the United States alone has imposed. Like most instruments of nonproliferation, it resembles the ritual war of primitive tribes in its dependence upon the good intentions of the participants.

such rockets without the intervention of an outsider—a Wernher von Braun. In fact, the two von Brauns of Brazil are Brazilian. There is Jayme Boscov, an engineer who declined to be interviewed for this article. According to his friend and colleague, Luiz Almeida, Boscov worked on the Concorde project in France. Then, after some years there, Almeida says, French security evidently thought "Boscov" sounded a bit too Russian and let him go. Boscov and his French wife returned to Brazil, where, Almeida says, "he began the program that gave us the Sondas and the VLS." To Boscov, AEB president Gylvan attributes "the ability to build the motor."

The other father of Brazilian rocketry is João Verdi de Carvalho Leite, president of Avibras, which most observers say he created more or less single-handedly.

Mixing a batch of solid propellant is not something one tries at home. "We used everything you can imagine at that time," recalls Ajax Barros de Melo, who as a young Air Force officer helped direct Brazil's solid rocket development. "Petrol. Ammonium perchlorate. Some very nice explosions. Then polyurethane. Then we started to study polybutylene. Since 1976, we started developing our propellant with polybutadiene." At that point, he says, the rocketeers ran into a series of problems, which they were still trying to solve when the MTCR embargo kept them from getting outside help. Since importing technology was now out of the question, the Brazilians started from scratch. "Construct a propellant plant, develop the mixer, develop the pyrotechnics," Barros de Melo says. "We did all our development in solids. We had to use the infrastructure—there was none for liquids."

How did they do?

According to Robert Geisler, a solid rocket consultant formerly with the Air Force Rocket Propulsion Laboratory at Edwards Air Force Base, rather well. Their propellant's specific impulse at sea level—a measure of the stuff's bounce to the ounce—is 230.5, which, Geisler says, "is about where we were when we entered the ballistic missile era in the 1950s. You certainly wouldn't use it on a submarine." Still, "I think it's a good result. Not on the top of the heap, but for their technological level, that's darn good."

One of the many myths that swirl around the VLS project is that Brazil could not have attained success without the intervention of an outsider.

If all goes as expected, sometime during the southern hemisphere's spring, the motors tended by Bruno, fitted with nozzles and ready to fire, will be carted down a long asphalt road to the assembly tower nearing completion about half a mile away. From a satellite assembly building nearby, the SCD-2A that has languished in the INPE lab will be enclosed in a bulbous fairing and installed on the tip of the stacked solid motors of the first VLS-1.

When those first four solids ignite, Almeida will be part of the crowd in the blockhouse, playing a role he finds a bit excruciating—range safety officer. "My finger will be on the button," he says. Nobody wants to be the man who shoots this one down.

But last May Alcântara had some distance to go before range safety became an issue. The 72-foot service tower gleamed in the equatorial sun, but there was no great swarm of activity around it; one man squatted in its shade, shaping a piece of galvanized metal with hand and hammer. The tracks from the service tower to the pad were laid but unfinished.

That sense of incompletion pervaded the place, even the big brick and concrete control center a few miles away, where open arches and murals of painted glass overlooked tiers of empty offices. A computer center, whose French-built machines were being replaced with Brazilian ones, stood almost empty, as did the radar tracking and telemetry facility. Only the commanding officer's helicopter was parked on the airport ramp.

On a bluff overlooking São Marcos Bay, two neighborhoods of tidy red-roofed bungalows had been constructed—one for officers, one for enlisted men—and there were schools, commissaries, and dispensaries, mostly deserted. Down the road another cluster of new housing, called NASA City for its use in the Guará Campaign, was quiet except for some industry technicians. Not long from now, the silence of this remote spot will be shattered by the roar of rocket motors.

The Brazilian site has already attracted the attention of the big players in the space launch sweepstakes. Lockheed Martin, as the international marketer of the U.S. Atlas and Russia's Proton rocket, has expressed interest. Dos Santos says he's been contacted by Boeing, an Israeli company, and France's Aérospatiale. A team from Rockwell International has visited. Ukraine has proposed using its big Zenit booster to launch Brazilian satellites from Alcântara and sharing its highly evolved liquid rocket technology with Brazil.

With its homegrown satellites and its long-awaited rocket, Brazil plans four launches between now and 2001 and hopes to gain the experience to turn its launch center into a Brazilian Kennedy or Kourou. "It's going to be a big business in the future, we think," dos Santos says. Not quite finished, still unpopulated, still unproved, Alcântara waits for the VLS series to mark the end of one long journey and the beginning of another—in space.

Average thrust: 327 kN vac
Burn time: 59 s (62 s action time)
Attitude control: nozzle flexure up to 3° pr
yaw TVC; roll managed by solid thrusters

WATSON'S

When the U.S. military wanted to learn about jets, American pilots had to take lessons from the Germans.

WHIZZERS

by Phil Scott

For a fighter pilot, life gets pretty dull pretty quick once a war is over. During World War II, Lieutenant Robert Anspach had racked up 86 combat missions, but in the days following Germany's May 1945 surrender, he had little to do as he waited around for the Army to decide where to send him next. Then word came down that the brass was looking for pilots to do some work with German jets.

It wasn't clear what that work was, exactly, but the pilots chosen would get to go home soon and avoid the danger of being shipped out to the Far East. Anspach and another guy from his unit, Captain Fred Hillis, were picked for an interview. They flew to Frankfurt.

Anspach knew nothing about jets, German or any other kind. Up to then, he had had only a single brief encounter with one. It was toward the end of the war, and his group of P-47 Thunderbolts had been flying cover for B-26s near a field at Lechfeld that the Messerschmitt aircraft company used for flight testing Me 262s, the world's first operational jet-powered warplane. From out of nowhere, a jet—some said two—flashed past and fired at them. *Wow*, Anspach thought. "Would you look at him?" one pilot said over the radio. "Let's go get him," said another, but by then the airplanes were gone.

It was pretty much the same story for Lieutenant Roy Brown, another P-47 pilot who'd heard something about a jet project. "I was young, it was a new experience, and it involved flying," says the taciturn Brown. "It was also a chance to get back to the States." He had been married only five months before being shipped overseas 10 months earlier. So he went for the interview.

A few days later, Anspach, Hillis, Brown, and several other pilots were dispatched to the Lechfeld airfield. Anspach says that to this day, he doesn't know exactly why he or any of the other pilots were chosen for the project. On the one hand, "I think that both of us [he and Hillis, who is deceased] had over 1,000 hours of flying time, so I would suspect that would be the primary thing," he says. On the other hand, the Me 262 had two engines, and he had never flown twin-engine aircraft.

The charismatic Colonel Harold Watson (above, flanked by two unidentified Germans) headed up an unusual postwar collaboration, detailing a group of American pilots to take flying lessons from their former enemies. The Americans were amazed by the speed of the Germans' Me 262 jet fighters. "I'm talking about greased lightning," one recalls today.

PHOTOGRAPHS: NATIONAL AIR INTELLIGENCE HISTORY OFFICE

When the pilots arrived at Lechfeld, they met Robert Strobell, who was to lead the mysterious project. Strobell had as much jet experience as the other Americans. He had been given the assignment by Colonel Harold Watson, whom he barely knew. Strobell had been stationed in Vital, France, and one day Watson, the director of maintenance in the Ninth Air Force Service Command, came barreling into the young pilot's office. "This is all we know about the Me 262," he said, dropping a few papers on Strobell's desk. "I want you to draw field gear and go to Lechfeld, Germany. I want you to train pilots to fly it and crew chiefs to maintain it." Watson had already arranged for a couple of dozen German mechanics and test pilots to help the Americans detailed to Lechfeld.

Hey, wait a minute, Strobell was about to say, but Watson had already spun around and marched out. The next day Strobell was in a C-47 transport flying to Germany.

At the beginning of World War II, the Allied forces had little hard information about enemy aircraft, except what could be derived from combat reports and the occasional crashed or captured aircraft. After the United States entered the war, the military put together an operation called Air Technical Intelligence. One of its centers was at Wright Field in Ohio, and from there intelligence officers would issue "black lists"—lists of enemy equipment they wanted to study.

The ATI was especially interested in the aircraft that the Luftwaffe fielded in the final days of the war. Some were a quantum leap ahead of anything the Allies had: the Me 262, the hot-dog-shaped Arado Ar 234 jet bomber, and the tiny single-engine Heinkel He 162, a jet fighter with plywood wings. As the war ground to an end, the Germans turned out aircraft with a more desperate edge—there was a manned version of the V-1 buzz bomb, and a plywood rocketplane called the Bachem Ba 349 Natter, which took off vertically and carried 24 small anti-aircraft rockets in its nose.

These machines were unable to turn the war in Germany's favor, but still it was critically important to study them, as they represented the coming generation of weapons. The ATI's philosophy was that such advancements should belong to Us instead of Them, especially if the next Them was going to be Japan. After all, the war in the Pacific continued with no end in sight, and it was known that the Nazis had shipped at least one Me 262, with blueprints, to its Axis partner via submarine.

And so Operation Lusty was born. "Lusty" was an acronym fashioned from "Luftwaffe Secret Technology," and ATI assigned Harold Watson to head up the operation. It was a two-pronged effort. One group, led by Captain Fred McIntosh, would retrieve the piston engine aircraft on the black list, and another group—Strobell's—would take care of the jets.

Strobell spent his first night at Lechfeld alone in a shot-up barracks littered with shards of glass. He slept in a bedroll on the floor, a .45 automatic in his hand; for good measure he had strung a bunch of cans across the building's stairwell.

The next morning Strobell got a good look at the aircraft strewn about the field. Among the miscellaneous Luftwaffe airplanes was a type Strobell had never seen: the swept-wing, jet-powered Me 262 fighter.

Some of the jets were missing their clocks and other instruments; freed laborers roaming the countryside had removed them, hoping to trade the equipment for food. Some airplanes had been accidentally damaged by troops from the Allied occupation forces who were unfamiliar with them. Of the thirty-odd Me 262s that were eventually found, only a few were airworthy. The black list called for 15 in flying condition.

A group of American maintenance technicians who had been assigned to Lechfeld joined forces with the German crews to restore as many Me 262s as possible to flying condition. In *Me 262: Stormbird Rising*, Hugh Morgan quotes one of the Americans, Master Sergeant Eugene Frieburger, recalling that "several of these aircraft were found to contain five-pound blocks of TNT underneath the pilot's seat," perhaps left by Germans unhappy at the thought of Allies taking possession of the jets.

A couple of days after the arrival of Anspach, Hillis, and several other pilots assigned to the project, Watson himself landed at the field to brief the men on their mission: getting the ex-Luftwaffe craft in good enough shape so that they could be flown to Cherbourg, France. From there, they would be loaded onto a carrier and brought back to the States so they could be studied. "My first vision of Watson was quite inspiring," Anspach says. "He was an extremely handsome man, a Flash Gordon type. A lot of people likened him to Steve Canyon. He seemed to be very sharp, and we thought we were getting into a pretty good deal with him."

Strobell was more critical of his new commander. "At that time I judged him to be quite egotistical and self-centered," he says today. "But he was an organizer and a mover and a shaker. I give him a lot of credit for it."

Among the arrangements he'd made, Watson had lined up several Messerschmitt test pilots to help the Americans at Lechfeld. There was Ludwig "Willi" Hofmann, who before the war had set several world records in gliders, and Karl Baur, who as Messerschmitt's chief test pilot had enjoyed a certain status and privileges. The Americans took to calling him "Pete." Eu-

Fred Hillis and Robert Anspach were among the first American pilots to arrive at Lechfeld (left).

American mechanics named the unarmed reconnaissance 262 above Marge*; the pilots later renamed it* Lady Jess IV. *The Americans got checked out in a two-seat 262B they named* What was it?

gene Frieburger tagged Baur as uncooperative—never volunteering information and speaking only when spoken to.

By early June, the mechanics had the first Me 262 ready. Still wary of the Germans, Strobell let it be known that Baur would make the first flight. Strobell had the ground crew pump only a half a tank of fuel into the Me 262 and told Baur to check it out. With that Baur took off. He remained in the vicinity of the field for 15 minutes, then landed.

When the 262 rolled to a stop, Strobell, Anspach, and another American pilot, Ken Holt, were there to meet him. When Baur got out of the cockpit, Strobell got in and taxied back to the hangar, where he had an American crew service the airplane. Back at the end of the runway, Strobell fired up the twin engines and took off.

More than a half-century later, Strobell recalls his first jet flight in vivid detail. "I made three pilot errors," he says. First, he tried to raise the nose too soon, which kept the jet from reaching takeoff speed; realizing his mistake he shoved the nose back down and let his speed build, then pulled the jet's nose up in the last microsecond. "I let it run down all 6,000 feet of a 5,000-foot runway," he recalls, laughing.

Gradually climbing 200, 300, 400 feet, he looked out and saw his wing slats opening and closing. With no radio on board he couldn't call the Germans and find out if this was an actual problem, but within a few seconds the airplane built up enough speed so that the slats stayed closed, and he forgot all about it once he had the landing gear up and tucked away.

He took a second to look at the countryside. For the first time he realized how fast he was flying. "I'm talking about greased lighting," he recalls, sounding amazed even today. "I had speed I never dreamed of—unadulterated speed."

He spent a few minutes checking his instruments within sight of the airport. Coming in to land he was still flying too fast to lower the landing gear without ripping it off in the slipstream, and pulling off the power didn't seem to help. By now he'd overshot the runway—pilot error number two.

He turned the jet around and pulled its nose up to bleed off airspeed, and then, still in a climb, he lowered the gear. But when the gear came down the airplane pitched up, and he discovered that he had climbed some 3,000 feet. That was error number three. The door on the nose gear, he quickly realized, was acting as an airbrake.

But now that the gear was down and he was in level flight, Strobell could set up for landing. "That first landing was smooth—not even hot," he says. "I had it right down and it quit just about when I wanted it to."

As he got out of the cockpit, Holt and Anspach pulled up in a jeep. They took Strobell's U.S. Army Air Forces collar insignia, a small pair of gold wings with a silver prop, and broke the blades off, leaving just the spinner. "It was a spur-of-the-moment thing," says Anspach. "I went up to him and said: 'You don't need these,' then broke them off." Explains Holt: "We were all hotshots who wanted to be different."

Later, though, when the exhilaration had worn off, Strobell got to thinking: *Why didn't the German pilots tell me about the slats and how to kill the speed and about the nose pointing up?* After mulling it over a few days, he concluded that because the Germans who had briefed him were test pilots, all the things that had scared the hell out of him would have been routine to them.

The young pilot came to believe that the Germans' loyalty lay with the Messerschmitt company, not the Third Reich. Of all the Germans at Lechfeld, only one was ex-military. When he showed up several days late decked out in full Luftwaffe regalia and driving his girlfriend in a red convertible sports car, Strobell, disgusted, told him his services weren't needed.

But as for the other Germans, they

The Americans had ruined a couple airplanes at Lechfeld by trying to tow them by the nose; they had better luck towing by the main gear (top).

On the way to Melun, the aircraft above, originally named after Master Sergeant Eugene Frieburger's wife, suffered a turbine failure and crashed.

NASM

The Whizzers and the Germans were able to work together peaceably. Top, left to right: Hillis, Hofmann, Watson, Holt, Baur. Bottom: William Haynes, Strobell, Anspach, unknown, Kenneth Dahlstrom, Brown.

were proud of their airplanes and their skills, and they seemed eager to get the jets flying, even for the Americans. Once they led Strobell to a haystack on a farm, where Lechfeld personnel had hidden six new Junkers Jumo engines back when Allied bombers were hammering the field. Aircraft designer Willy Messerschmitt also supported the Americans; in *Me 262: Stormbird Rising*, Watson recalled, "He was delighted that we were doing this, as it meant that his work would not be lost."

As the Germans revived more jets for the Americans, a collegial relationship developed between the former enemies. In addition to paying the Germans for their work, "we would supply these people with K-rations and what other type of rations we had," recalled Eugene Frieburger. "But what pleased them the most was that periodically I would go out and shoot a German Rehbuck, which is a small deer. Back on the aerodrome we would cut off a few steaks for our own use, and give the rest to the German mechanics to take home to their families."

The mechanics eventually lined up a flight of 10 jets, their Luftwaffe crosses and swastikas obliterated by freshly painted American insignia. The pilots began the process of getting checked out in the 262, familiarizing themselves with the cockpit layout, the German instruments, and the airplane's flight characteristics. They practiced lighting the Jumo engines on an unairworthy 262 that the mechanics had chained to the ground. About a week later, each strapped into a two-seat 262B with Baur and flew a quick lap around the field. "I like to say the first time I saw a jet, I flew it," says Anspach.

That first flight, he continues, "was just to give us the feeling of the aircraft in its takeoff and landing modes, and mainly to realize that when you pull that throttle off you don't start slowing down—there was nothing up there like a prop to start slowing it down.

"Nothing extraordinary to it, except maybe the lack of noise. On our landing we came from far out.... Once you got committed to land, you're going to land—the whole trick was getting it on the ground."

After each pilot landed, someone was there to break the props off his collar insignia.

"Once they had gotten the feel for the airplane, they decided they were now jet pilots and they were all pretty proud of themselves," says Watson's wife Ruth (Watson is deceased). "Hal was going back and forth to headquarters and he didn't think he should deface the insignia, but he was pretty proud of them for doing it."

In addition to resuscitating the jets, the team assembled enough spare parts to keep the jets flying through their shakedown in the States. ATI wanted tools too, since the German equipment was metric and the United States was an all-Standard nation, so Watson told Strobell to pack up the Germans' tools as well. But when the Army trucks started off toward Cherbourg, no metric tools were on board. "In America we have the capability to fabricate anything," Strobell says. "But those tools were those people's livelihood—no way was I going to take a man's livelihood away."

June 10, 1945, was the day the pilots were to start ferrying the 262s toward Cherbourg. Each American embarked on the first leg of the trip—a 365-mile flight to Melun, France. None had more than maybe 30 minutes of jet flying time, and none had ever flown a jet solo.

"My flight to Melun was uneventful," Brown recalled in an interview with Norman Malayney, who wrote about Operation Lusty in a series of articles in the *Journal of the American Aviation Historical Society*. "I glanced at the engines periodically. The controls were responsive and the plane was easy and a pleasure to fly—especially compared with the relatively sluggish P-47. The flight was quiet and vibration free. Another difference was its high speed. I found myself busy going through my maps quickly, one after another."

Watson, though, had problems. "On the way I had to make a forced landing at St. Dizier because I found that I didn't have enough fuel to get to Melun," he recalled. "While the landing was OK, taking off was a different matter, and they had to cut down some trees so I could clear the runway perimeter."

Once at Melun, the pilots waited. And waited. Days went by. Eventually Strobell learned what they were waiting for: General Carl Spaatz, chief of the U.S. Army Air Forces in Europe, who would eventually serve as the first head of the independent Air Force. Watson wanted to show Spaatz what the Me 262

could do, and Strobell was going to lead the demonstration. There were to be no Thunderbird-style aerobatics; just Strobell, Holt, and Hillis in a well-spaced "rat race," or trail formation, putting the jet fighters through three or four fast passes with some mild low-level maneuvers.

The demonstration went well, but at the end, Strobell could not resist trying to impress Spaatz by doing what he now calls "the most stupid thing in my life": pulling the jet's nose straight up and performing a barrel roll. The stunt could have resulted in a flamed-out engine, but luckily, it went off without a hitch. Watson later recalled Spaatz saying to him: "Hal, that's a wicked aeroplane. Wicked, WICKED! I'm sure glad that they [the Germans] screwed up the tactical use of this aeroplane."

It was at Melun that the group got the nickname that it's known by today. They had drawn a design for a shoulder patch—Donald Duck riding on a jet engine around the globe—and they wanted a name to go with it. Anspach came up with Watson's Whizzers ("I mean, we were just whizzing around in the air").

On the final leg of the mission—Melun to Cherbourg—things began to unravel.

The pilots were flying with no radio and no navigational equipment. Anspach encountered slightly overcast conditions and ascended for a clearer view. Upon descent, he found that he'd overshot the port city and was over water, so he made a 180-degree turn. Now he could see his destination, but there was no way that he would be able to make it: "About this time I was on fumes," he says. "I saw an island with a grass landing strip on it, which turned out to be the Isle of Jersey, and I put it in there."

The arrival of a German jet shocked the British troops stationed there. "Who are you? Where did you come from?" they demanded as Anspach emerged from the cockpit. Once he explained, a soldier told him that he'd seen the aircraft's main gear barely clear the steeple of one of the island's churches.

Something even more harrowing was in the offing, however.

Of all the 262s at Lechfeld, Watson most prized one with a long 50-mm nose cannon, so Strobell had assigned his most experienced pilot, Willi Hofmann, to fly it. Halfway to Cherbourg, one of its turbines failed. As the jet began to shake apart and plunge toward the ground, Hofmann struggled to shut down the other engine, keep the nose up, unbuckle his seat belt, and open up the canopy all at once. He managed to roll the jet on its back and got bucked out of it. When the French found him near the smoking hole left by his aircraft, Hofmann was a mess, but he survived. (Some brass suspected that Hofmann had crashed the aircraft deliberately to keep it out of Allied hands. At one point Strobell heard that he was going to be court-martialed for assigning Hofmann to fly the airplane, but that never came to pass.)

Not long after, Strobell prepared to leave Cherbourg for Mannheim, Germany, to pick up his personal gear. As

NASM

The 262s were shipped to the States on the HMS Reaper*, along with Ar 234s, Bf 109s, Fw 190s, and an assortment of other German aircraft the Americans wanted to study.*

In addition to pioneering jet technology, the Germans brought a modern sculptural sensibility to aircraft design (opposite).

Me 262: The First Operational Jet Warbird

SOURCE: *WARPLANES OF THE THIRD REICH*, W. GREEN, DOUBLEDAY

SPECIFICATIONS, Me 262A-1a
Wing span: 40 ft. 11.5 in.
Length: 34 ft. 9.5 in.
Height: 12 ft. 7 in.
Max gross weight: 15,720 lbs.
Engines: Junkers Jumo 004B (two), 1,980 lbs. static thrust each
Armament: 30-mm MK 108 cannon (four)
Max speed: 540 mph @ 19,685 ft.
Range: 526 mi. @ 19,685 ft.
Initial climb rate: 3,937 ft./min. @ 19,685 ft.

he was taking off, his P-47 Thunderbolt, officially classified as "war weary," blew up. He had just enough altitude for his parachute to open up, and he spent 45 days in the hospital recovering from burns. All his flight records from his Lechfeld days, plus some 20 rolls of film, were destroyed.

While Strobell recovered, the Luftwaffe aircraft arrived at Cherbourg and were given a coat of preservative to guard against sea salt, then loaded by crane aboard the British aircraft carrier HMS *Reaper.* The *Reaper* transported them across the ocean to New York. From there, the airplanes were brought to Newark, then flown when possible—or trucked when necessary—to their new American homes.

Roy Brown's Whizzer days were over. "By that time," he says, "they had come out with the point system for getting out of the military, and I had enough points." He returned to his bride.

Anspach and Holt helped ferry some of the German aircraft to Freeman Field in Indiana, one of the U.S. depots for evaluating foreign aircraft. On one trip, Holt had to land in Pittsburgh and his brakes weren't working. "I could see a cornfield at the other end of the runway," he says. "I figured I'd run out into the cornfield and stop, but there was a 30-foot drop-off at the end of the runway.... I hit flat and broke the cockpit behind me and knocked the canopy off." Holt doesn't recall getting out of the airplane, but he does recall looking back and seeing the 262 in flames.

As for Strobell, when he finally reached the States, he was assigned to Freeman Field to write an Me 262 checklist for American pilots.

In the months that followed, Watson and the ATI set about wringing secrets from the German aircraft and data. Swept wings, like those of the 262, turned out to work better than straight wings for aircraft operating near the speed of sound, so designers began to use them for U.S. fighters, such as the North American F-86 Sabre jet. And the newly independent Air Force used the German craft for non-technical purposes as well, flying a few at airshows to dramatize America's need for jets.

But it wasn't long before the hard-won airplanes of Watson's Whizzers were almost all gone. Some had already followed Hofmann's aircraft and crashed in transit or during tests. Some were transferred to the Patuxent River Naval Air Station in Maryland, but eventually the Navy deemed them too maintenance-intensive; it canceled its evaluation project in March 1946. The jets that had been allocated to Patuxent River were eventually bulldozed under as landfill for a runway extension.

By May Freeman Field was closed, and the foreign aircraft stationed there were placed in storage.

Of the German jets that survive in this country, all arrived through Operation Lusty. Holt's, which he had named *Ginny H.* for his fiancée, now resides in the National Air and Space Museum's Jet Aviation gallery. And Strobell's is in the Air Force Museum at Wright-Patterson Air Force Base in Ohio. "I've gone to see it several times," he says.

Harold Watson stayed in the service, eventually reaching the rank of major general. "When he was an invalid the last few months of his life, a number of military retirees living here in Florida would come and visit him," says Ruth Watson, "and I'd hear gales of laughter coming from his den. But he was always impressed with the young men who were the Whizzers because they were young and enthusiastic and all darn good pilots."

FIELDS AND STREAMS

WITH RADIO, X-RAY, AND ULTRAVIOLET TELESCOPES, ASTRONOMERS HAVE CAUGHT THE SOLAR WIND IN THE ACT.

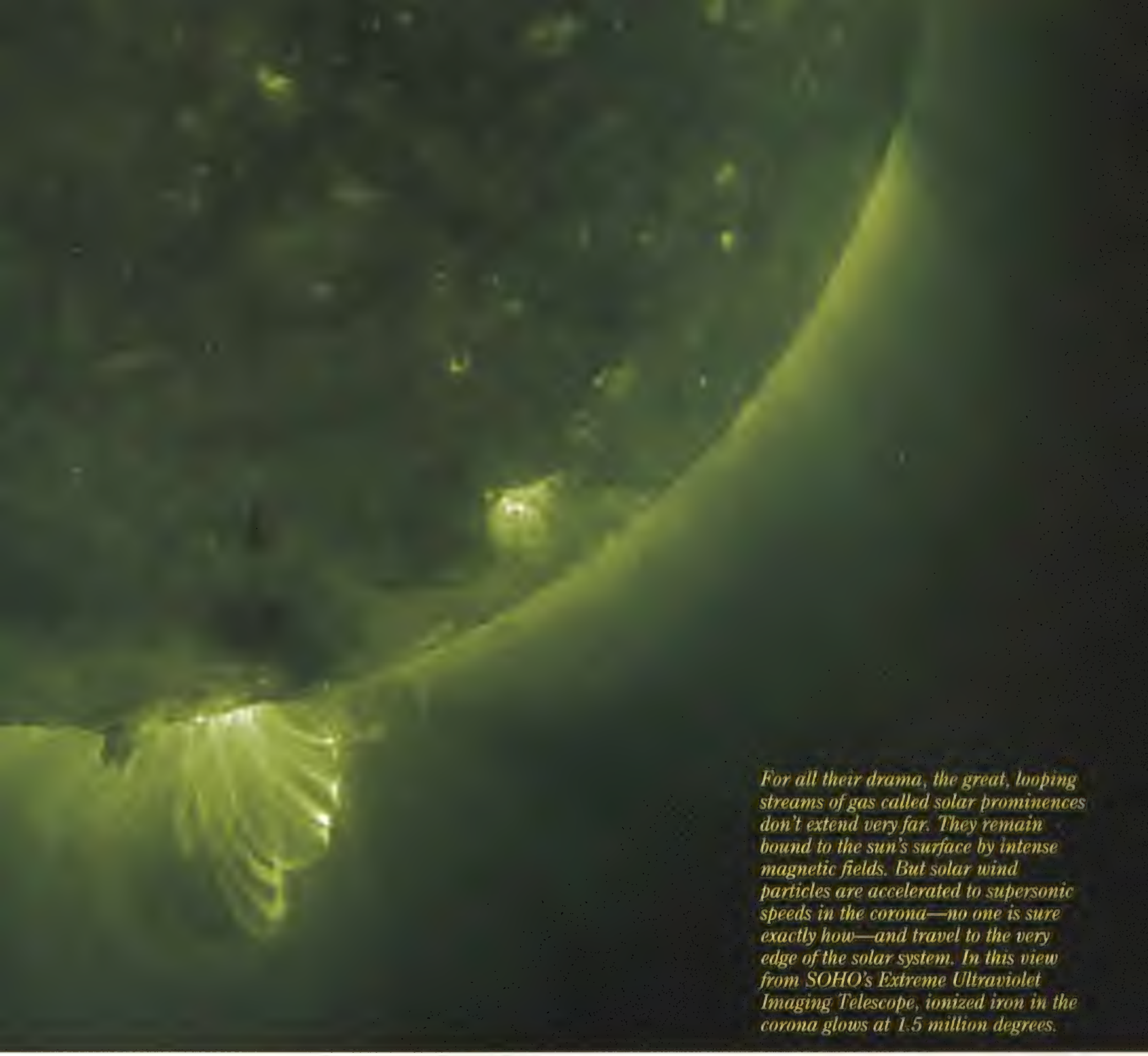
by Tony Reichhardt

Space is neither as empty nor as peaceful as it seems. Every second of every day, a blizzard of atomic particles—the escaping outer atmosphere of the sun—blows through the solar system and washes over Earth. A large eruption on the sun can fling billions of tons of matter into space, knocking perfectly good satellites out of service and causing brilliant auroral displays that hum with more electricity than the United States generates in a typical day.

Mapping the solar system's invisible magnetic fields and its rapidly flowing streams of charged particles is a very tough business. Nothing is simple or straightforward. The "solar wind" of atomic particles doesn't stream out in nice, neat rays like those in a child's drawing; it sprays like water from a spinning lawn sprinkler as the sun rotates. And it drags the sun's magnetic field along with it, so when the Ulysses spacecraft looks down from above the solar poles, it sees a field shaped like a pinwheel. And that's just on calm days—a magnetic storm on the sun can throw the whole pattern into chaos. Embedded in this constantly changing flow are planets, moons, comets, and various other rocks, each with its own electromagnetic properties, each engaging the solar wind in its own peculiar way.

It used to be that space physicists, who piece together this mind-bending puzzle for a living, had little to show the public for all their hard work. At NASA press conferences their arcane data plots and diagrams of weird, twisting field lines would go all but ignored while the planetary geologists, who had prettier pictures, got all the attention.

No longer. In the last few years a small fleet of spacecraft launched by the United States, Europe, Japan, Russia, and other nations, many under the auspices of the International Solar Terrestrial Physics (ISTP) program, have returned torrents of data—and, yes, pretty pictures—that have revolutionized the way scientists interpret the sun



For all their drama, the great, looping streams of gas called solar prominences don't extend very far. They remain bound to the sun's surface by intense magnetic fields. But solar wind particles are accelerated to supersonic speeds in the corona—no one is sure exactly how—and travel to the very edge of the solar system. In this view from SOHO's Extreme Ultraviolet Imaging Telescope, ionized iron in the corona glows at 1.5 million degrees.

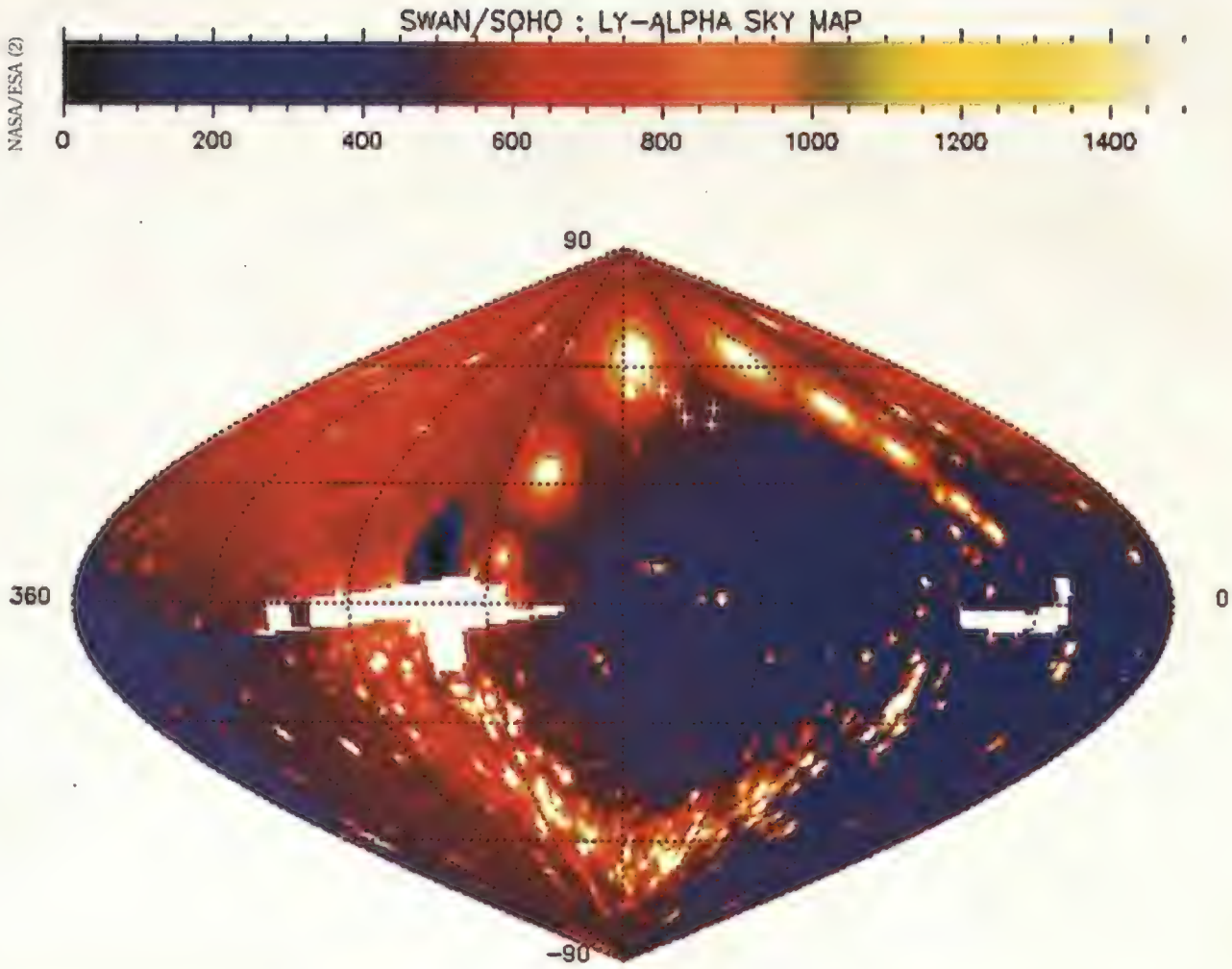
NASA/ESA

and its output. The spacecraft—Ulysses, Yohkoh, Geotail, Wind, Polar, SAMPEX, the Solar Heliospheric Observatory (SOHO), and several others—serve, in effect, as weather stations between Earth and the sun, observing across the electromagnetic spectrum. Together, they have liberated scientists from their single, constrained vantage point here on Earth and have given them their first glimpses of the heliosphere—the sun's domain—in glorious 3-D.

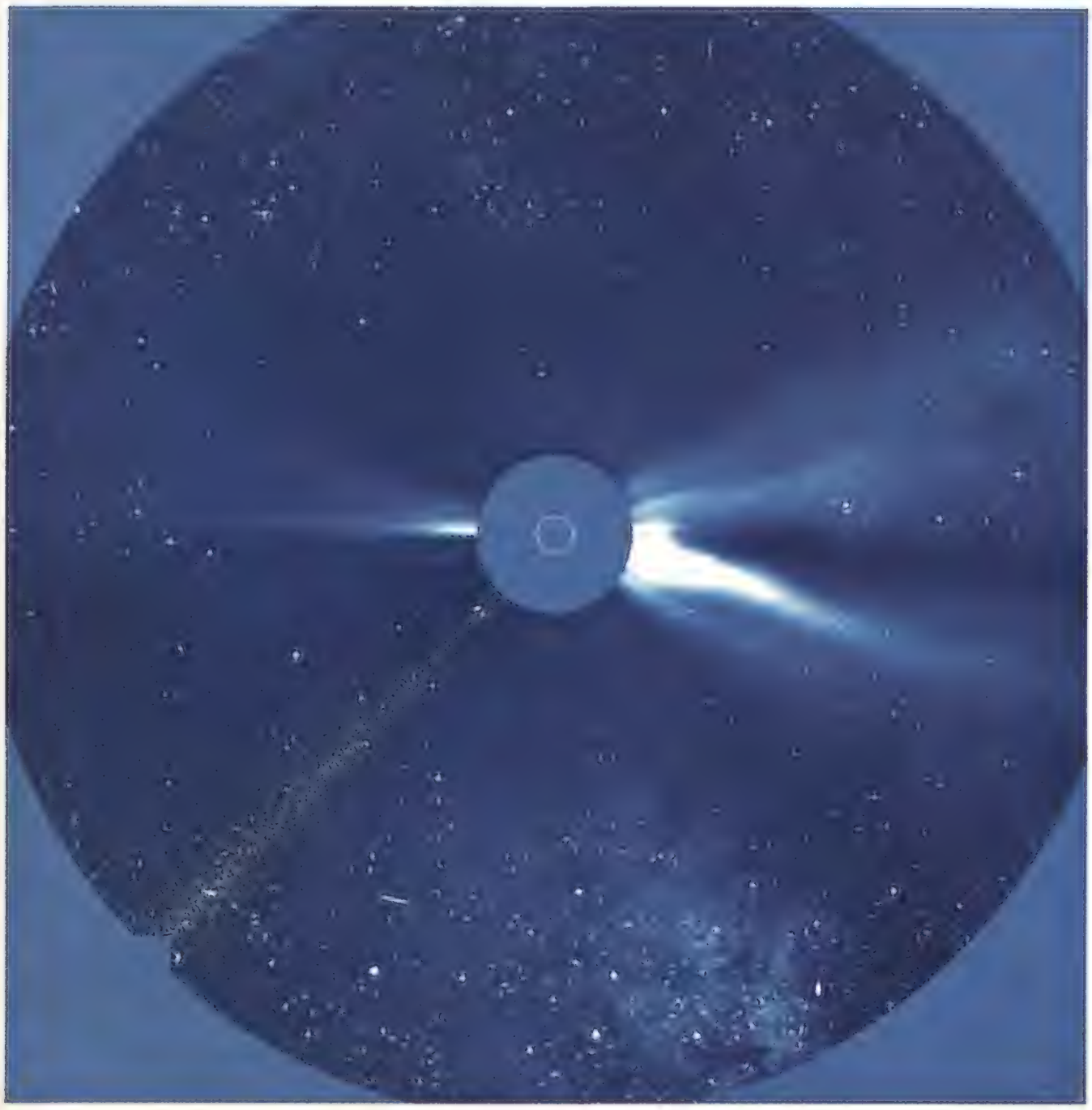
The new data and images have in turn fed new theoretical models and scientific visualizations, resulting in spiffier presentations to laypeople and serious researchers alike. "It is impossible to make progress with just line plots anymore," says Mario Acuña, ISTP project scientist at NASA's Goddard Space Flight Center in Maryland.

Part of our interest in solar-terrestrial physics is practical. Space storms of the kind that struck Earth in January of this year have economic repercussions. When Earth's magnetic field is pumped up by a storm, satellite electronics can be damaged. Electric power grids on the ground feel the surge, as do oil pipelines, which act like large wires. Even atomic clocks with finely tuned magnetometers have been known to hiccup. The ISTP spacecraft and their successors could act as an early warning system.

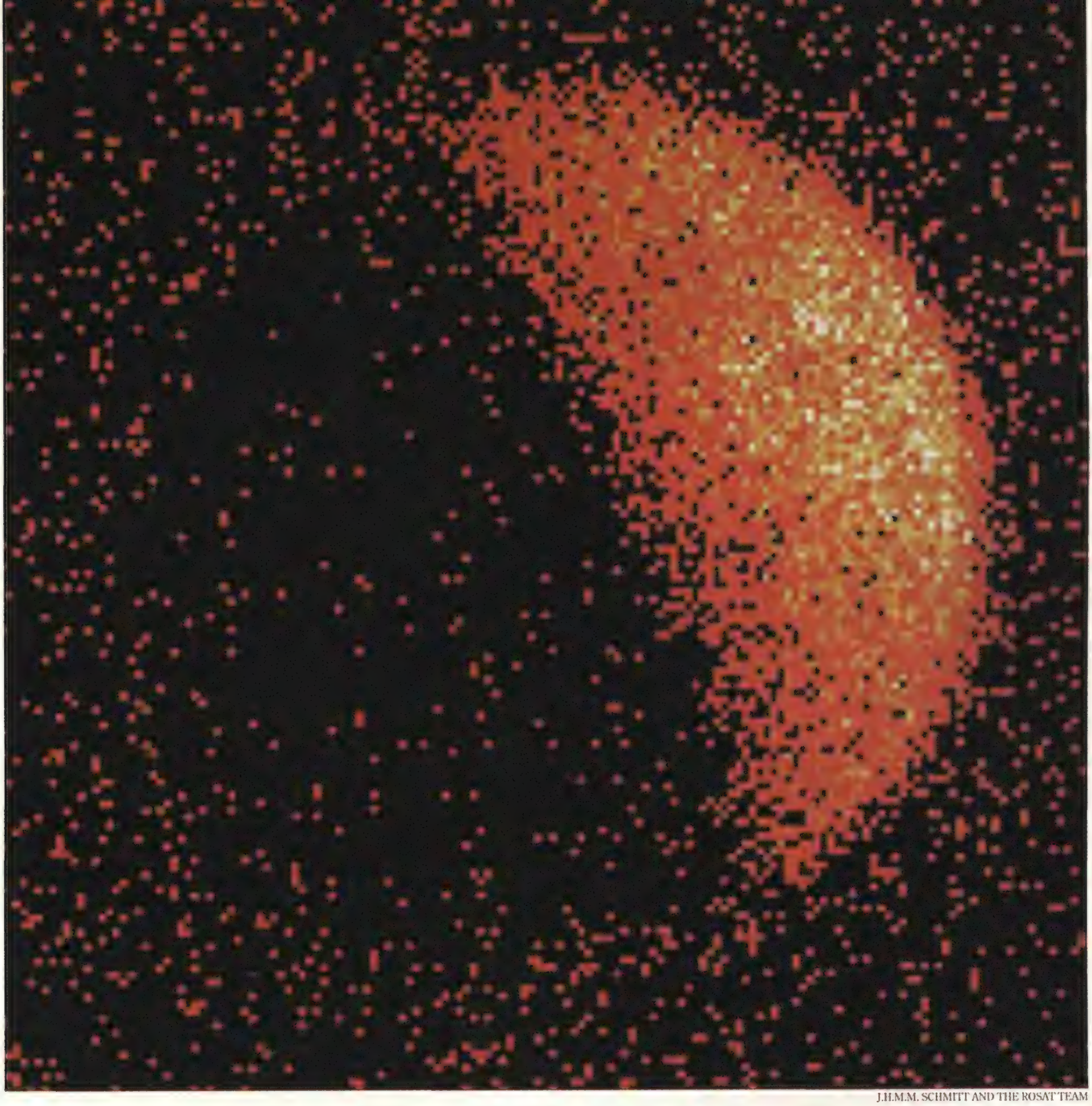
NASA is now planning the next generation of space physics missions, including an interstellar probe that would travel upstream in the direction of the sun's motion to sample material coming from other stars. That, says Christopher Russell, a space physicist at the University of California at Los Angeles, would build on the kind of direct measurements we're now making for the first time in our own neighborhood. "All we're doing [today] is probing a small part of the universe and learning how it works," he says, with appropriate awe. "There's a vast universe out there that we can't get to right now."



By mapping interstellar hydrogen (right), scientists can see a crude footprint of solar wind activity. Hydrogen-rich regions upwind of the sun's motion through space (toward the left of the picture) appear red and yellow, while blue regions show where solar wind protons—hydrogen atoms stripped of their electrons—have interacted with the more common variety of hydrogen in our solar system. As a bonus, SOHO's SWAN instrument caught the track of Comet Hyakutake's hydrogen cloud as it rounded the sun (masked out at left of center).



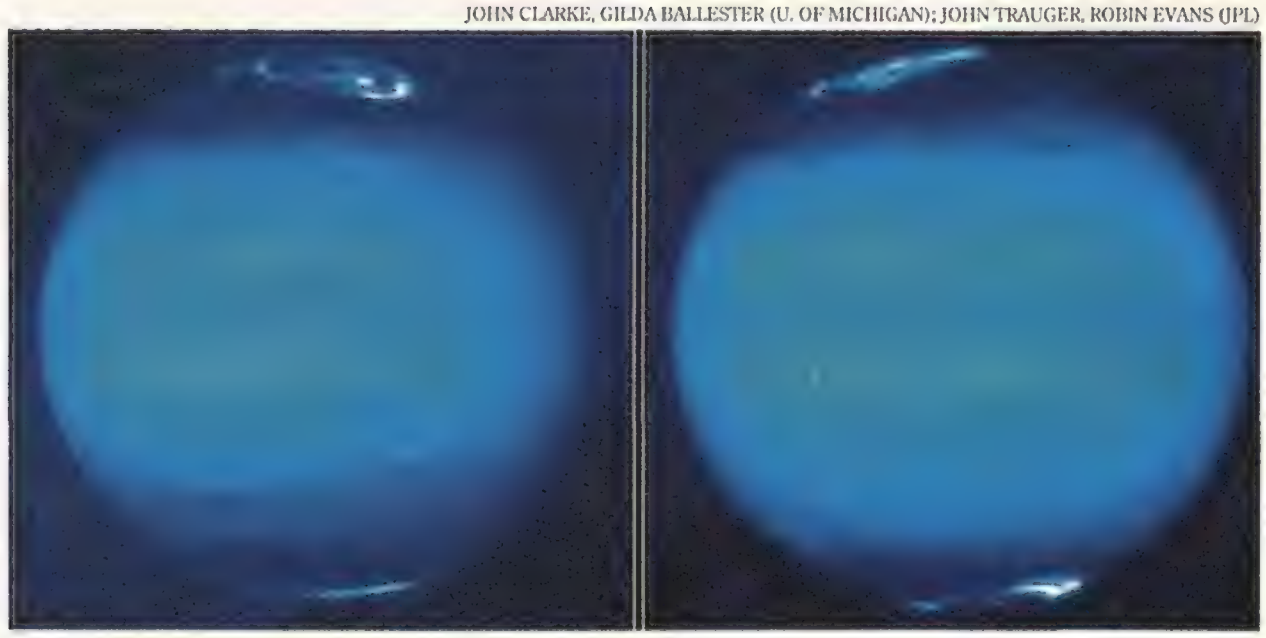
The solar wind regularly gusts into hurricanes known as coronal mass ejections. An instrument called LASCO (Large Angle Spectrometric Coronagraph) on board the SOHO spacecraft blocks out the solar disk and highlights the material being ejected, which in this image stretches almost 14 million miles—halfway to the planet Mercury.



J.H.M.M. SCHMITT AND THE ROSAT TEAM

Even a cold, dead body like the moon is energized by the stuff that pervades space. In this image made by the ROSAT satellite, the sunlit face shines brightly in reflected X-rays. Because the lines of the sun's magnetic field are curved, some of the hydrogen and helium ions in the solar wind also travel to the dark side, causing the lunar dust to fluoresce. Over the eons, the solar wind has deposited enough helium-3 in the lunar soil—more than a million tons, by one estimate—to serve as a possible source of revenue for moon colonists. That isotope of helium, rare on Earth, would be ideal for future fusion reactors. If it could be mined on the moon, helium-3 might become the first extraterrestrial resource with real economic value.

JOHN CLARKE, GILDA BALLESTER (U. OF MICHIGAN); JOHN TRAUGER, ROBIN EVANS (JPL)



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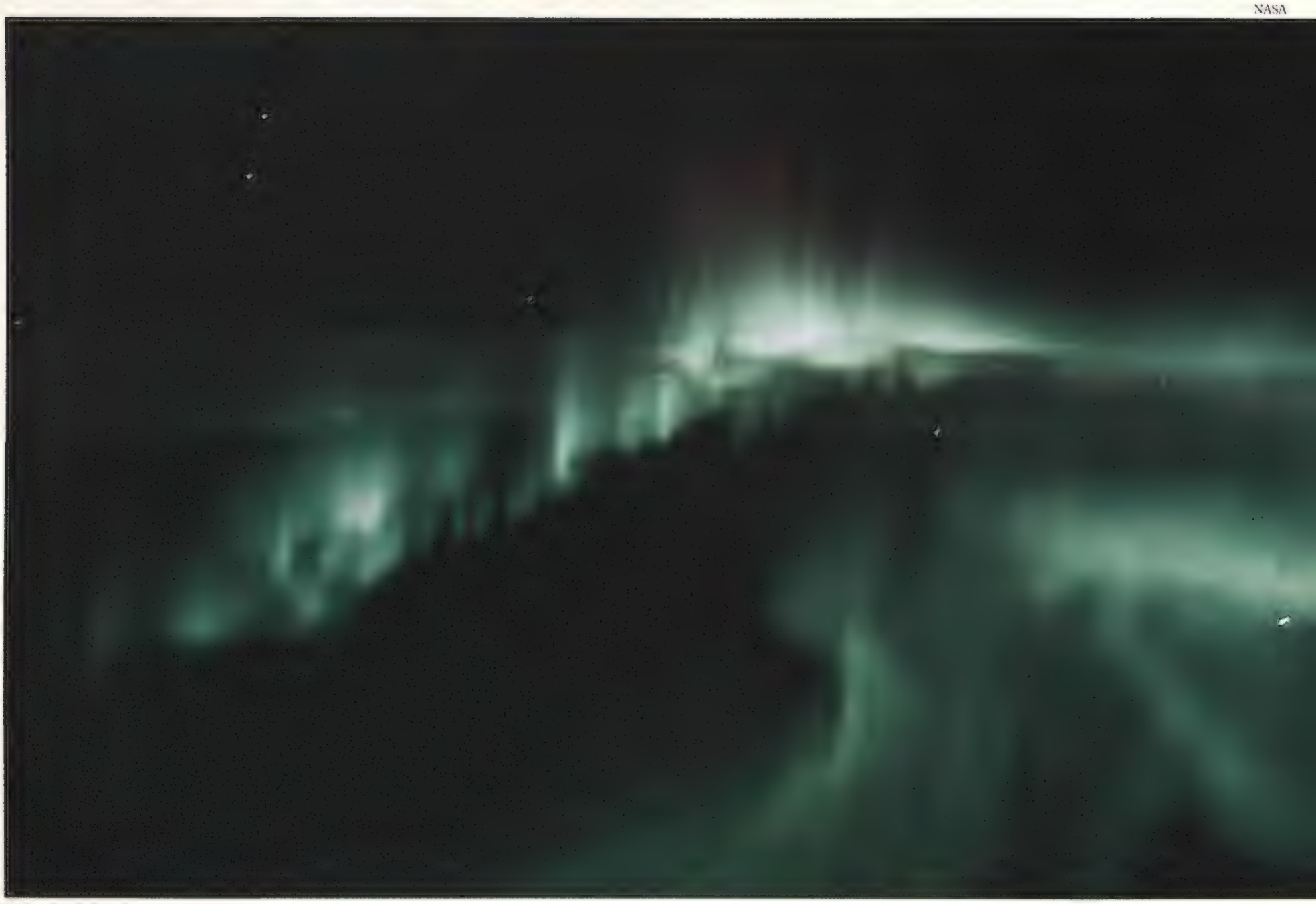
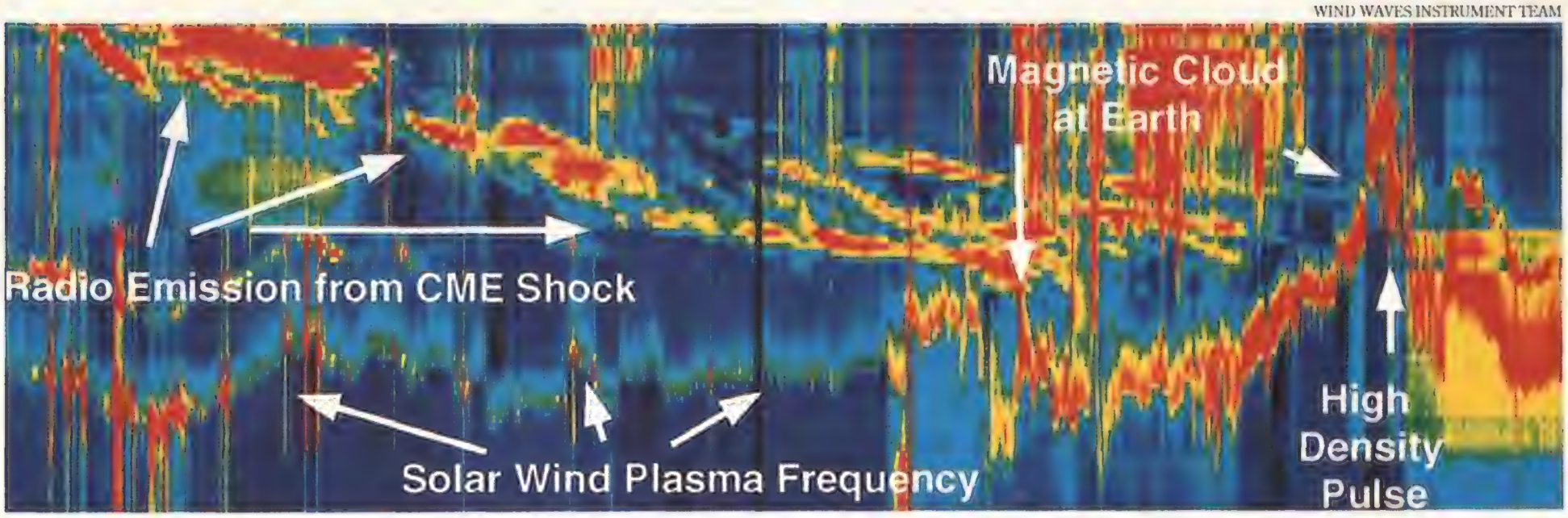


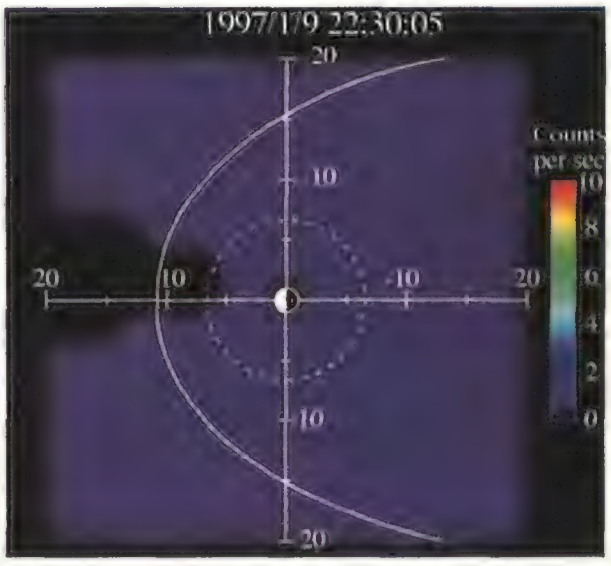
Auroras glow in northern and southern skies when incoming solar wind particles are funneled by Earth's magnetic field lines toward the poles, where they excite gases in the upper atmosphere. "We haven't found a way to image the field lines," says UCLA space physicist Christopher Russell. But photos taken by shuttle astronauts (above) come close, he says. "You can see the lineations and imagine where the magnetic field might be."

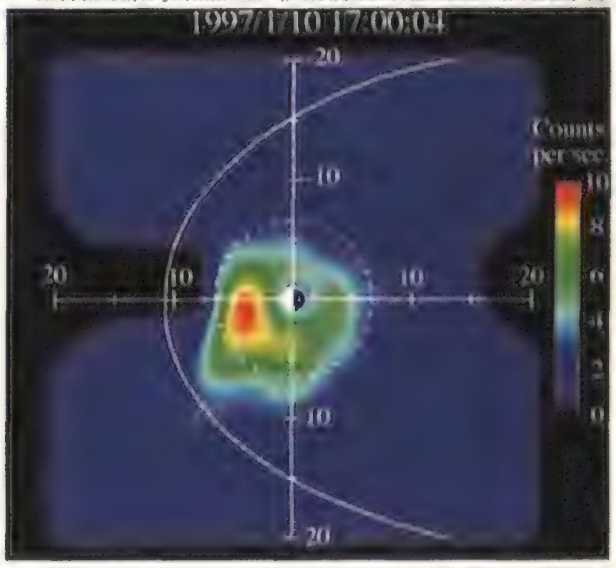
Jupiter also has auroras, but their power derives from the planet's rotation, not the solar wind. Complex interactions between Jupiter and its volcanic moon Io create a donut-shaped region of intense radiation surrounding the satellite's orbit. The planet and moon are further connected by an arcing, magnetic "flux tube" that crackles with two trillion watts of current. The Hubble Space Telescope's ultraviolet view of Jupiter (top) shows bright auroras at both poles, as well as a tiny "footprint" just below the northern aurora (top, left), where the flux tube hits the planet's atmosphere.

WIND WAVES INSTRUMENT TEAM



H. SPENCE, A. JORGENSEN (POLAR/CEPPAD SCIENCE TEAM) (2)



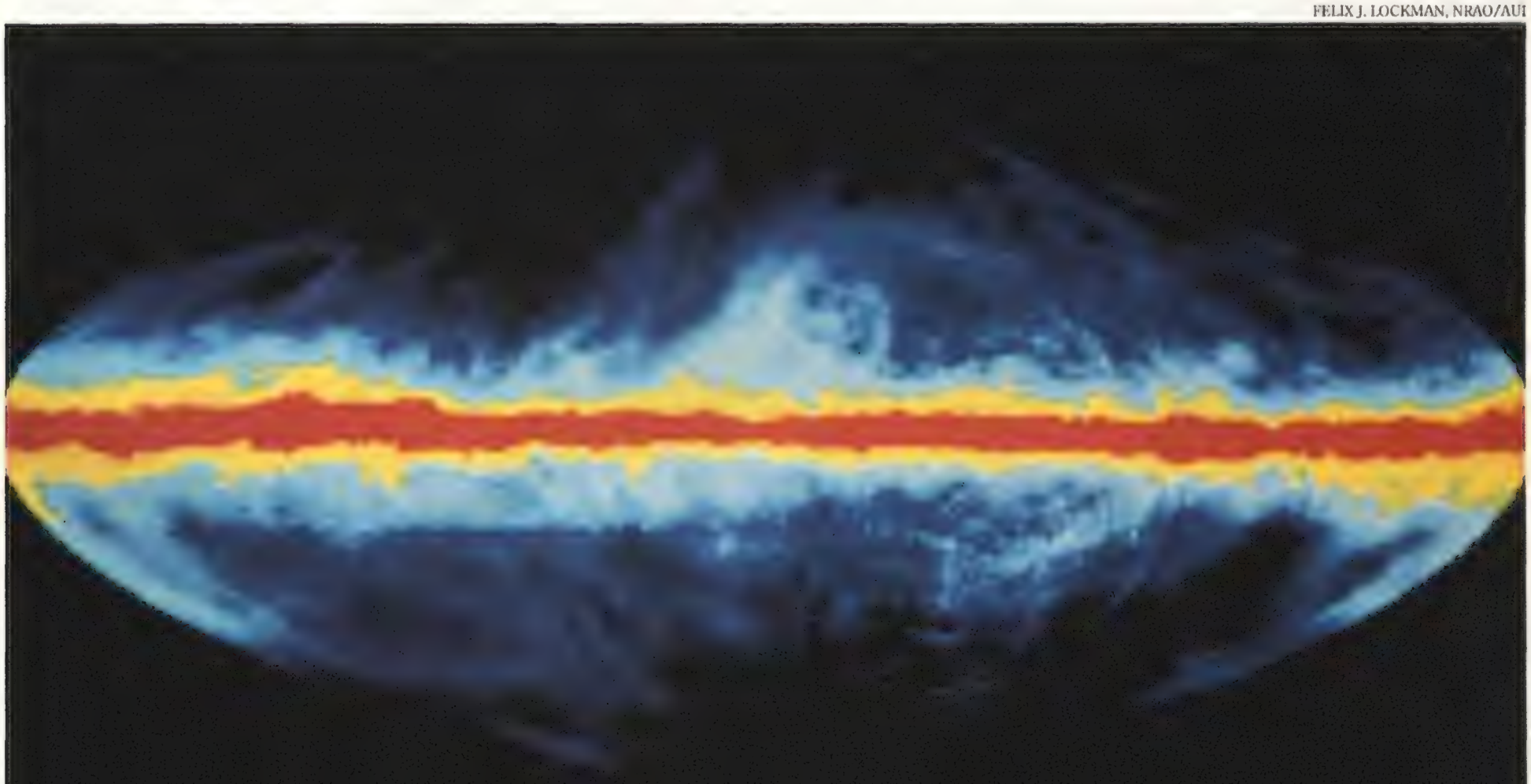


January 11, 1997, was a bad day for AT&T but a great one for space physicists. Five days earlier, the sun had hurled an enormous blob of gas in our direction. For the first time, spacecraft sensors posted at various locations in the inner solar system were able to track one of these coronal mass ejections from birth to Earth.

The LASCO instrument onboard SOHO watched the blob leaving the sun and tracked it until it became too diffuse to see. Then the WIND spacecraft, stationed between Earth and the sun, monitored low-frequency radio emissions—like a series of sonic booms—coming from a shock wave at the leading edge of the cloud as it plowed through the thin material pervading space at 300 miles per second (top). When the storm hit Earth on January 10, WIND saw even stronger pulses of radio energy. The POLAR spacecraft in Earth orbit also saw signs of the event. On January 9, all was calm (above, left); the next day, Earth's magnetosphere lit up as protons in the arriving solar wind affected hydrogen atoms surrounding Earth (above, right). The day after the cloud roared by, AT&T lost contact with a $200 million Telstar satellite in orbit—apparently a victim of the storm. Based on the 24 hours it took to pass through our neighborhood, scientists estimate the cloud was 30 million miles thick.

The sun and its retinue of planets move through the vastness of interstellar space, which has, in turn, its own electromagnetic fields and streams of gas and charged particles. This all-sky view, taken at radio wavelengths, shows thin clouds of interstellar hydrogen in the space between the stars. The plane of our Milky Way galaxy runs horizontally across the center.

FELIX J. LOCKMAN, NRAO/AUI



>SIGHTINGS<

U.S. AIR FORCE 50th ANNIVERSARY

BRUCE DAVIDSON/MAGNUM PHOTOS INC. (6)

Manhattan photographer Bruce Davidson, whose most recent book of photos is *Central Park*, was on hand for the Golden Air Tattoo commemorating the 50th anniversary of the United States Air Force at Nevada's Nellis Air Force Base last April. "I had never been to an airshow," he says. "I never would have dreamed of it. But I had photographed Sheila Widnall, the Secretary of the Air Force, recently and had toured with her for several days, and I became sensitized to the beauty and power of military aircraft. When I learned that the Air Force was to have a gigantic airshow and exhibit I was intrigued by the idea of looking at it as an assignment.

"This was the first time I had photographed high-speed aircraft zooming by at low altitudes, and I was a novice. I couldn't track them. Then I noticed that civilians were

shading themselves under the giant wings of a huge B-52 bomber, as if the shadow of the wing was protecting these people. I zeroed in on the human dimension of the show, the family of man gathering under large aircraft at high noon in the piercing desert light. I looked for the little vignettes, like a child playing with a machine gun on an HH-60 helicopter and the mechanics and pilots beneath the wing of a B-2 stealth bomber, inspecting it.

"I was quite taken by the peregrine falcon being held by one of the air academy cadets. I knew it was the fastest bird of prey, faster than some propeller-driven aircraft. It was a privilege to be that close to such a magnificent bird and peer into the black hole of its eye."

INDEPENDENCE DAY

USAF

Beyond the Wild Blue *by Walter J. Boyne. St. Martin's Press, 1997. 442 pp., b&w and color photos, $29.95 (hardcover).*

The foundations of airpower developed during World War II, coupled with the introduction of the jet engine and the beginning of the cold war, provided the basis for the inauguration of a unique military service—one created solely because of the advance of technology. As the Air Force reaches the half-century mark, Walter Boyne, a former director of the National Air and Space Museum, has given us a concise primer that is both a narrative history and a quick-reference source of facts and statistics.

Boyne's book doesn't retell the rich history of airpower that includes World War II, other than to show how it provided a foundation for the creation of the Air Force. He takes the reader through a quick rehash, noting that Billy Mitchell was already advancing the idea of a separate military air service as early as 1916. Mitchell would be court-martialed for his views in 1925, and fellow airpower visionary Henry "Hap" Arnold would speak in his defense at the trial.

Mitchell and Arnold were premature, as Boyne notes. The time for independence would come just two years after the defeat of Germany and the blooming of mushroom clouds over Hiroshima and Nagasaki that preceded Japan's surrender. Boyne outlines the inevitable political struggles that ensued, particularly those instigated by Navy leaders smarting at the perceived abandonment of what had been, until then, the preeminent image of military might—an American warship.

The new service, created on September 18, 1947, when Stuart Symington was sworn in as the first Secretary of the Air Force (left),would be tested in rapid succession by the Berlin Airlift and the Korean war, as well as its assumption of the initial responsibility to provide the nation's capability to wage nuclear war. It was this role—projecting power worldwide—that would continuously shape the Air Force mission.

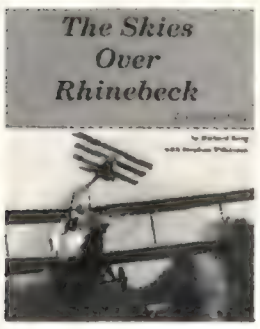
Boyne's book is divided into short, sometimes disassociated segments that outline periods of history in broad strokes and nearly 100 pages of appendices and chronologies conclude the volume. The downside for some readers may be a lack of cohesion and a slightly choppy ride—Air Force involvement in Cambodia during the Vietnam war, for example, is explained within its own section in 16 lines, sandwiched between discussions of operations in Laos and a more extensive passage about the Linebacker II air offensive.

To be fair, Boyne has attempted—and mostly achieved—the package of a complex series of ideas and views. He covers the airplanes and weapons, but also deals with the seemingly mundane, including the development and far-reaching implementation of total quality management principles by key Air Force leaders in the 1980s. The oft-derided "quality movement" today affects every Air Force activity, from flying and maintaining aircraft to preparing food in an Air Force dining facility.

Boyne gives us the drama of aerial combat over "MiG Alley" and above the skies of Vietnam and Iraq, but also provides insight about the men and women who shaped the Air Force for the last half-century, as well as discussions of the geopolitical events that have forced continual refining of the service's mission. *Beyond the Wild Blue* outlines a story that every bluesuiter can be proud of.

—John Sotham is an associate editor of Air & Space *and a maintenance officer in the Air Force Reserve.*

The Skies Over Rhinebeck: A Pilot's Story *by Richard King with Stephan Wilkinson. Rhinebeck Aviation Guild, 1997. 259 pp., $45.00 (hardcover).*



For nearly 40 years, over a modest little airfield near the Hudson River in upstate New York, aviation history has been both preserved and made. Over the years, this grass strip, fashioned out of an abandoned farm, has become the mecca for those passionate about the aircraft of the earliest days of powered flight. The distinctive profiles of Sopwiths, Fokkers, and Blériots and the unique drone and clatter of Le Rhône, Mercedes, and Anzani engines have become routine sights and sounds at this airport. The place, of course, is the world-renowned Old Rhinebeck Aerodrome Museum.

In *The Skies Over Rhinebeck*, Richard King, with the help of *Air & Space* contributing editor Stephan Wilkinson, has produced a charming and entertaining account of Old Rhinebeck's years under the leadership of the Aerodrome's founder and guiding light, Cole Palen. King, who joined Palen at the very beginning, helped build the Aerodrome into what it is today—one of the most distinctive and fascinating flying organizations anywhere. His memoir tells the stories of the historic aircraft that are the heart of the Rhinebeck experience, but he also brings to life the interesting and dedicated personalities who have contributed to the Aerodrome's success.

Beyond a history of the Aerodrome, *The Skies Over Rhinebeck* is also a collection of great flying stories. King has done a good job of putting the reader in the cockpit and conveying the thrills and spills of flying these wonderful old aircraft. As you read each episode, you find yourself wondering, "And how is he going to get out of this one?" There is a certain edge and excitement to the stories that makes for a good read, regardless of whether you are a pilot. King provides an especially good sense of what is required to fly pioneering machines made of wood, canvas, and steel.

Finally, the book is a visual treat. It is illustrated with dozens of action photographs of the striking aircraft that have rolled down the runway at the Old Rhinebeck Aerodrome for four decades. Readers will be turning the pages for hours long after they devour the rich and informative text.

—Peter L. Jakab is curator of early flight and World War I aviation at the National Air and Space Museum.

Fire and Air: A Life on the Edge *by Patty Wagstaff with Ann L. Cooper. Chicago Review Press, 1997. 346 pp., $24.95 (hardcover).*

Patty Wagstaff, three-time U.S. Unlimited Aerobatic Champion, assisted by Ann L. Cooper, weaves a tale of global adventure, competition aerobatics, and a search for affirmation. Cooper, whose credits include *Tuskegee's Heroes* and *The Flying Aces Air Circus*, rounds out the story and helps render the essence of Wagstaff's spirit, drive, and humor.

Much of Wagstaff's transient childhood was spent in Japan, rebelling against numerous parochial schools' menus of guilt, virtue, and discipline. While eschewed in early adulthood, these values return to stand her in good stead when she later discovers a passion for flying and competition aerobatics.

Wagstaff relives her years in San Francisco during the hippie heydays of the late 1960s. She describes her first marriage to a treasure-hunting Australian sailor at the age of 21, and recounts her move to Alaska, which truly would influence how she would spend the rest of her life.

While in Alaska, Wagstaff matured and took pride in gaining a position with the Bristol Bay Native Association in which she held more responsibility than she ever had: administering government grants as well as directing and organizing native economic development in the region. After the failure of her first marriage, she became acquainted with Robert Wagstaff, a local attorney and pilot.

In Alaska, flying is synonymous with mobility, so it's not long before Wagstaff is a passenger in Robert's Cessna 185. Robert also holds an instructor rating, and in no time Patty is learning to fly. Her developing love of flight is closely matched by her growing love for Robert; they marry after a four-year relationship.

Wagstaff's rise to prominence as an aerobatic force is fueled by unconditional support from Robert, her ambition to be the best, and her conviction that the only way to achieve her goal is through hard work and a rigorous training schedule.

Fire and Air: A Life on the Edge isn't just a story with the potential to inspire every pilot to go bore holes in the sky. It's a tale that encourages us to experience the exuberance of finding the best in ourselves.

—Alyson Behr, a technology and aviation journalist, is a competition aerobatic pilot.

BRIEFLY NOTED

U.S. Carriers at War *by Peter Kilduff. Naval Institute Press, 1997. 128 pp., color and b&w photos, $31.95 (hardcover).*

Contains many detailed photos from World War II carrier operations, as well as gripping accounts from pilots like Norman Sterrie, who made the last landing aboard the heavily damaged *USS Lexington* during the battle of the Coral Sea. The carrier was eventually abandoned and sunk by a Navy destroyer to keep it from being captured by the Japanese.

Walk Around: P-47 Thunderbolt *by Lou Drendel. Squadron/Signal Publications, 1997. 80 pp., color and b&w photos, $14.95 (paperback).*

Included are well-lighted color photos of a P-47D cockpit, as well as other areas of interest to modelers, like landing gear and engine details. As with most *Walk Around* volumes, color illustrations are included—noteworthy is a rendering of a P-47D that served with a Mexican squadron in the Philippines during World War II. Comparative diagrams trace the development of the rugged Thunderbolt from its ancestors to the late-production P-47N and the never-produced XP-72.

Spitfire Leader *by Max Avery with Christopher Shores. Grub Street, 1997. 188 pp., b&w photos, $29.95 (hardcover).*

Evan "Rosie" Mackie accumulated 20 aerial victories flying Supermarine Spitfires and Hawker Tempests for the Royal New Zealand Air Force during World War II. Journalist Max Avery teams with historian Christopher Shores to tell the story of New Zealand's top-scoring ace.

The 350th Fighter Group in the Mediterranean Campaign *Shiffer Publishing, 1997. 81 pp., $19.95 (paperback).*

History in the raw: a reprint of the official history of the 350th, including candid photos of pilots standing beside their recently flak-riddled aircraft and grainy mess hall shots of Thanksgiving turkeys. Includes a sobering roll of airmen killed in action or taken prisoner.

UFO Crash at Roswell: The Genesis of a Modern Myth *by Benson Saler, Charles A. Ziegler, and Charles B. Moore. Smithsonian Press, 1997. $24.95 (hardcover).*

It's been 50 years since the summer of 1947, when debris was found on a farm near Roswell, New Mexico. The nature of that debris and what became of it are at the center of a hot controversy that has produced an entire cottage industry based on a story, which, according to this book, meets the strict and scholarly definition of a modern myth.

Weep for the authors, for they will be vilified by those who ardently believe that the events at Roswell are the tangible proof that Earth has been visited by sentient alien beings whose spacecraft met with misfortune and crashed. The book doesn't set out to change the believers' minds, but in the process of analyzing the fabric of the myth, it rends it, and this is certain to be resented.

An analysis of the evolution of the Roswell tale through iteration and revision takes up the first two sections, which are authored by Brandeis University anthropology professor Charles A. Ziegler. The author's primary intention is simply to demonstrate that a modern tale, passed along by traditional means as well as more sophisticated modes of modern communication, can meet social science's criteria for categorization as a myth.

In the third section, Charles Moore, a participant in a number of balloon experiments during the period of the initial discovery of debris, provides a long technical explanation for his belief that the debris was entirely consistent with the apparatus he and his colleagues assembled during their experiments to develop high-altitude balloons for a secret program to detect the sounds generated by atomic tests.

In the final two portions, Benson Saler and Ziegler draw upon the body of published works in their scholarly world to establish what connections, if any, may exist between the Roswell myth and what we commonly think of as religious elements. While this portion will be of most interest to scholars and of least interest to ordinary civilians, read it anyway, because it leads fairly naturally to the conclusion, wherein the final arguments are made that the Roswell events can be evaluated outside the logic of mythology, that the tale of an alien landing has not been (and is unlikely ever to be) accepted by mainstream science or journalism as factual, and finally, that much of the reason for all this is that we all watch too much television, thereby rewarding bad television production, which leads to bad programs that treat the Roswell myth as if it were real. The bad programs lead people to believe the myth and demand an investigation from their Congressional representatives (such as the one recently conducted by the U.S. Air Force and immediately derided by true believers as a whitewash). The final nail in the coffin is that this is costing you, Mr. and Mrs. Taxpayer, a pile of money for silly investigations and diverting funds from worthwhile projects.

The authors are on solid ground when they examine the entire Roswell phenomenon from their perspective as scholars and scientists. But the conclusion is discordant and petulant in tone after the patient examination that precedes it. To the extent that it is perceived as advocacy for terminating further serious examination of the Roswell events, the believers will howl it down as further evidence of high-level coverup, this time—gad!—from the higher education establishment! Face it: Nobody can change television.

—George C. Larson is the editor of Air & Space.

A-Train: Memoirs of a Tuskegee Airman *by Lt. Col. Charles W. Dryden, U.S. Air Force (ret.). University of Alabama Press, 393 pp., b&w photos, $29.95 (hardcover).*

Colonel Charles Dryden's memoirs, as told in his book, are peppered by disappointment. The reader seeking a page-turner full of daring tales of aerial combat will be disappointed with *A-Train*, but that reader will be overlooking the real drama contained within the book's chapters.

Although Dryden saw his share of combat as a fighter pilot in the Sicilian Campaign during World War II and later in Korea as an airborne forward air controller, he treats these important episodes as a backdrop to his real battle, which was with the Jim Crow system of segregation.

It is impossible not to share his resentment about a system so dedicated to his isolation, especially as he recounts how he and his fellow black pilots were denied use of the post exchange cafeteria at Waterboro Army Air Base in South Carolina, while German POWs were admitted simply because they were white. He is enraged at a system so inflexible in its execution that it would subvert the talents of a large group of dedicated, patriotic men determined to serve their country. "Bitterness? Yes! Oh yes!" Dryden writes. "Because of all the humiliations and insults we had to endure. Bitterness so strong and long lasting that even as this book is being written a half century later, the tears of hurt and rage still flow!"

Dryden demonstrated a zeal for being at the front of a movement. He became a pilot while still in college and began seeking out the Army Air Corps well before it trained "colored" pilots. As a result, when the doors opened just prior to World War II, Dryden was among the first to enter the now famous Tuskegee Flying School in Alabama and became one of three graduates of the second class in the program that trained African-Americans to be military pilots.

Dryden's memoirs serve as an important account of the slow, frustrating climb through a system designed to thwart black pilots. His book is an important account of the battle for equal rights in the armed forces before, and after, President Truman's 1947 executive order mandating desegregation of the military.

Dryden persevered and retired after 21 years of service, always cognizant of his role as a challenger and as one determined to pursue his dreams—usually without his wife, who chose to remain in New Jersey and follow her own career.

Colonel Dryden is a brave and dedicated officer, aware of the injustices he suffered but always determined to do a job to the best of his abilities. I would have been proud to have flown on his wing.

—Lt. Col. Bob Hanson, U.S. Air Force (ret.), is a career fighter pilot who flew F-4 Phantom IIs in Vietnam.

Mining the Sky: Untold Riches from the Asteroids, Comets, and Planets *by John S. Lewis. Addison-Wesley, 1996. 288 pp., $26.00 (hardcover).*

John S. Lewis, a space researcher at the University of Arizona and a commissioner of the Arizona Space Agency, has written a passionate call to action, a hopeful and energetic plea for people to begin extracting the vast resources waiting relatively nearby in our solar system. Much of the book's value comes from the fascinating descriptions—and excellent

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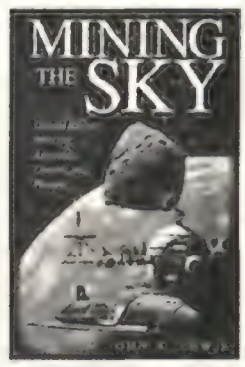


photos—of the composition and behavior of our neighbors in space: the moon, the asteroids and comets, Mars, even the gas giants Jupiter, Saturn, Uranus, and Neptune. Through Lewis' penetrating gaze, the skies come alive with possibility. The author believes in the need to commit resources soon for more unmanned exploration, then manned exploration, and finally colonization of space—all in the name of mineral and energy export to bolster what he perceives as Earth's sagging prospects.

Readers, though, must constantly keep in mind the author's own proviso that the book's contents represent what *can* be done, not what *will* be done. Lewis' new book (he is also the author of *Rain of Fire and Ice: The Very Real Threat of Comet and Asteroid Bombardment*) suffers from too many writing styles and from a puzzling refusal to realistically factor social issues into his sometimes glib calculations (the chapter introductions, written as passages of science fiction, are unreadable). Pared by a third and concentrating just on the astronomical information, this book could have been a blockbuster.

Who wouldn't marvel at the almost loving inspection of our moon: It looks like a dead rock to most of us, but to Lewis and the many other researchers he credits with sharing his vision, the moon is rich with material that can be used for further exploration of the solar system. Because the moon lacks an atmosphere, it doesn't exhibit certain expensive characteristics of Earth's deep gravity well and therefore could serve as an excellent waystation for working trips to other parts of the solar system. Portions of the moon's stark surface could be manipulated at the atomic level to yield enormous stores of oxygen for life support and for rocket propellant. Lewis covers so much detail about surviving and thriving on the moon that these few chapters could stand alone as a modern-day lunar primer.

Likewise, Lewis presents the latest information on comets and asteroids (their complexity and staggering mineral wealth, their dangers), on Mars as a possible refinery for rocket propellant, and on the moons of Mars as sources for such rewards as a trillion tons of water. The giant gas planets, he writes, lie ten years away in travel time but could yield enough hydrogen and helium for an almost infinite number of yet-to-be-built

fusion reactors. Throughout the book, the message is clear: Space should be seen as Earth's biggest inexhaustible source of virtually free energy and other vital resources.

Lewis urges governments to liberate space exploration and unleash the economic competition necessary for further progress. Despite his encouragement to use space for human prosperity, Lewis can't warm up the inherently cold and lonely—alien—feel of space, nor can he seem to understand how lovely Earth's lush and undeniably friendly face is to most of humanity; he writes in seeming exasperation about humans' reluctance to leave Earth and embrace his purposeful space travel. No matter how gruesome and intolerable life on the home planet becomes, some people will want to stay.

—Nan Chase, a former investigative reporter, now writes regularly for Hemispheres, *the in-flight magazine of United Airlines.*

Blind Watchers of the Sky: The People and Ideas that Shaped Our View of the Universe *by Rocky Kolb. Addison-Wesley, 1996. 338 pp., $14.00 (paperback).*

In recent years scientists have zestfully taken to writing popular accounts of their specialties. From Stephen Hawking's cosmological explorations in *A Brief History of Time* to Stephen Jay Gould's many publications on natural history, we are awash in frontline accounts of researchers, past and present, trying to make sense of Nature's book. In *Blind Watchers of the Sky*, Edward "Rocky" Kolb, director of the astrophysics group at the University of Chicago's Fermilab, offers a contribution to this often engaging, ever expanding genre.

Kolb's own specialty is the theoretical interconnections between particle physics and the cosmology of the very early universe—the Big Bang and its aftermath. His goal is to take us through the centuries-long effort to explain scientifically the phenomena of the heavens, culminating with our contemporary understanding of how the universe began and evolved. His story is told through the ideas and contributions of a pantheon of Western civilization's scientific greats, stretching from the ancient Greek Ptolemy to, in our own century, Einstein, Hubble, and Gamow.

Kolb seeks to place the reader in the milieu of the scientist. In an energetic, conversational style, he emphasizes the challenges of formulating and answering questions about the universe. He enlivens old and new problems by stripping them

to their essence and conveying how scientists' personalities, theories, observational methods and instruments, and other factors entered into the quest for knowledge. He extends this emphasis on problem-solving to the larger organization of the book. Three major sections present the reader with the specific questions that shaped the research of different eras. The first explores the efforts of thinkers through Newton to explain the solar system. Here Kolb's renderings of Tycho Brahe, whose words provide the title of the book, and Johannes Kepler are the most vivid (if not the most accurate) biographical vignettes in the book. The second covers the conundrums of understanding stars, nebulae, and the scale of the universe that challenged astronomers in the 19th and early 20th centuries. The last examines the articulation of the Big Bang theory and its place in modern cosmology. Throughout, Kolb draws useful connections among the emergence of new instruments (such as the telescope, spectrograph, camera, and atom smasher), skillful observation, and changes in our understanding of the universe.

Kolb's narrative style and organization yield a delightfully lucid overview of how—through the idiosyncracies, insights, and hard work of individuals—our knowledge of the universe has become richer and more complex. Yet the book does not seem to play to the author's real strengths. All of the historical material has been covered more carefully and with eloquence elsewhere. Oddly, the author's own field of research is the least developed part of the book. Perhaps Kolb would have produced a more distinctive book if he had turned his skillful eye toward his own scientific community and the challenges that face cosmologists around the world today. Maybe that will be his encore.

—Martin Collins is a space history curator at the National Air and Space Museum.

World War I Aviation: A Bibliography of Books in English, French, German and Italian *by John Noffsinger. The Scarecrow Press, Inc., 1997. 609 pp., $98.00 (hardcover).*

No aspect of the history of flight has been as thoroughly studied as the evolution of military aviation in the period from 1914 to 1918. There always seems to be room on our collective bookshelves for one more volume on the iron men and

wooden airplanes that fought the first great war in the air. John Noffsinger, a professor emeritus at the University of Kentucky and a distinguished historian of architecture, has produced a first-rate guide to the rich literature of the field in this annotated bibliography listing 4,217 items that are published in four languages.

A thorough revision and expansion of the author's earlier *World War I Aviation Books in English: An Annotated Bibliography* (1987), the new volume concentrates on materials in English. With a listing of 624 titles in German, 344 in French, and 157 in Italian, however, the book also serves as a useful introduction to the foreign language literature about the war. A bibliography of bound volumes, it does not attempt to describe the periodical literature. The annotations are especially well done, offering straightforward and objective descriptions that clarify rare and less well-known titles while avoiding subjective judgments on well-known works.

One interesting feature of the book is a checklist of more than 900 titles. Drawn primarily from sales catalogues and personal inspections of bookstore prices from 1990 to 1996, the list combines a price with an indication of the relative scarcity of each item.

If you can't afford this book, bring the volume to the attention of your local librarian. For what it's worth, you can explain that a reviewer in *Air & Space* magazine regards Professor Noffsinger's bibliography as the best English language guide to books on aerial warfare in the first world war.

—Tom Crouch is the chairman of the aeronautics department at the Natonal Air and Space Museum.

CD-ROM

Wings: London Blitz to Pearl Harbor *Discovery Channel, 1997. IBM and Macintosh compatible, $39.95.*

The fourth installment of the Discovery Channel's series of interactive CDs about airpower, *London Blitz to Pearl Harbor* features tours of English, Japanese, and German air bases, flight simulators, and educational features on air combat and specific aircraft. A searchable database allows access to movie clips and statistics. Other titles in the series include *Korea to Vietnam*, *Midway to Hiroshima*, and *Saigon to the Persian Gulf.*

CALENDAR

October 4
Auburn Air Fair: "Thunder in the Sky." Pancake breakfast, P-51 simulator, airplane and helicopter rides, remote-controlled aircraft demonstrations. Auburn Airport, CA, (916) 885-8260.

Georgia Pilot Pancake Breakfast and Acrobatic Seminar. Sponsored by EAA Chapter 690. Sport Aviation Center, Briscoe Field, Lawrenceville, GA, (770) 613-9501.

October 4 & 5
Airshow: "From Air Mail to Modern Flight." G.O. Carlson Chester County Airport, Coatesville, PA, (610) 384-9000.

October 5–10
"Aluminum Overcast," featuring rides on a B-17 Flying Fortress. Sponsored by EAA Chapter 186. Winchester Regional Airport, VA, (703) 354-6950.

October 7–12
Reunion: 94th Bomb Group, 8th Air Force. Cherry Hill Hilton, Cherry Hill, NJ, (408) 377-4787.

October 9–12
Reunion: Air Commando Association. Fort Walton Beach, FL, (904) 864-1953.

October 10–12
Northeast Aero Historians Meeting. National Soaring Museum, Harris Hill, Elmira, NY, (607) 734-3128.

Reunion: 50-9 Jet Fighter Specialists. DeGray Lake Resort, AR, (501) 245-2503.

October 13–17
Reunion: 368th Fighter Group, Fort Magruder Inn, Williamsburg, VA, (770) 455-8555.

October 14–17
North American Symposium on Small Format Aerial Photography. Cloquet Forestry Center, University of Minnesota, Cloquet, MN, (301) 493-0290.

October 19
Harriet Quimby Research Conference. Western Aerospace Museum, Oakland Airport, CA, (510) 638-7100.

October 31–November 2
Fox Field National Air Races. Fox Field Airport, Lancaster, CA, (805) 940-1709.

November 1
Fly-In Pancake Breakfast and Technical Seminar. Sponsored by EAA Chapter 690. Sport Aviation Center, Briscoe Field, Lawrenceville, GA, (770) 921-4423.

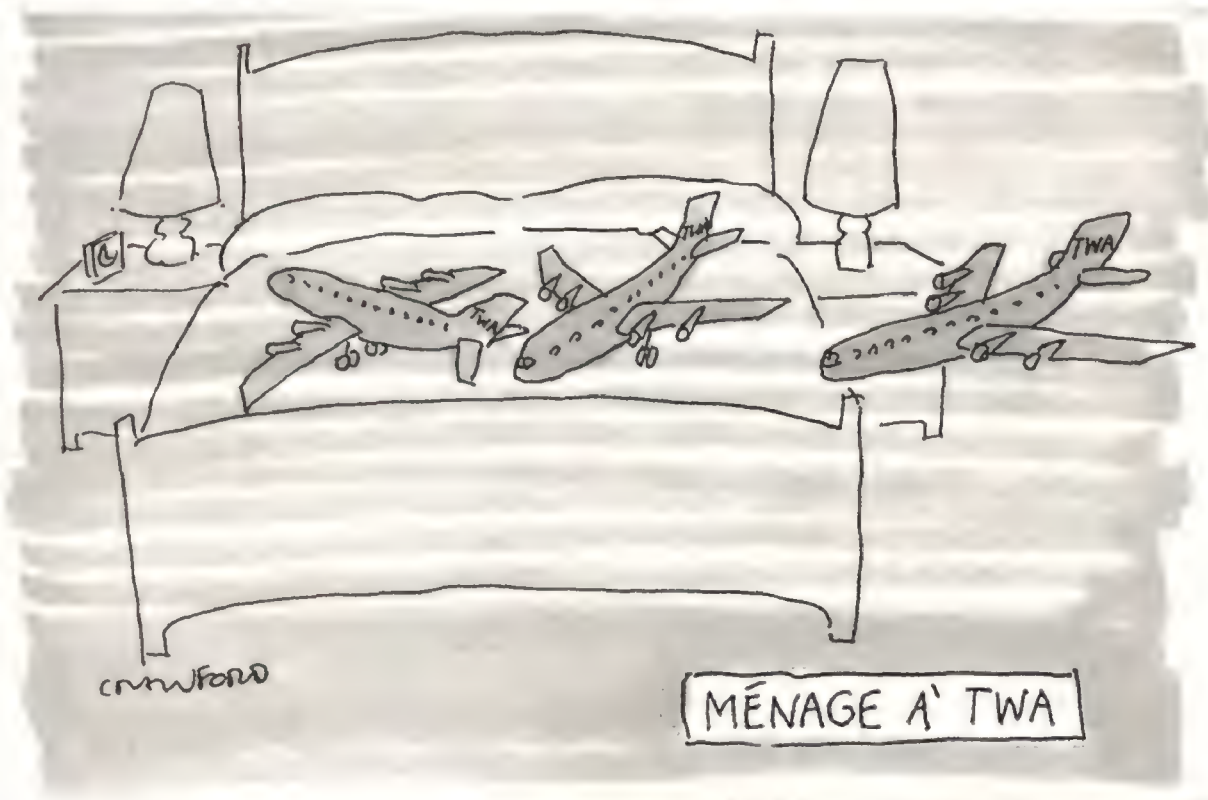
November 1 & 2
Wings 'n Things '97. Sun 'n Fun Air Museum, Lakeland, FL, (941) 644-0741.

November 6–8
International Conference on Alternative Aviation Fuels. Baylor University, Waco, TX, (254) 755-3563.

November 8
Fly Day Honoring Women in Aviation. Lone Star Flight Museum, Galveston Island, TX, (888) FLIGHT-8.

November 8 & 9
Daytona Skyfest. Daytona Beach International Airport, FL, (800) 854-1234.

Organizations wishing to have events published in Calendar should submit them four months in advance to Calendar, Air & Space/Smithsonian, *901 D St. SW, 10th Floor, Washington DC 20024. Events will be listed as space allows.*



CREDITS

Songs Sung Blue. John Starr is a writer and video producer living in Los Angeles. He finds it interesting that the UFO craze, the rebel biker movement, and the U.S. Air Force were all born in the same year. Starr would like to hear from Air Force veterans who knew his father during his flying days; he can be reached by mail via the magazine or by e-mail at John Starr1@aol.com.

Glendale Rising. Los Angeles-based freelancer Stephen Joiner is a technician in the film industry and a dreamer of buoyant flight. When jammed in freeway traffic, he scans the skies for the return of the great airships.

Tankers. A former Air Force intelligence officer, Reina J. Pennington is a Ph.D. candidate in history at the University of South Carolina.

Further reading: *Building a Strategic Air Force*, Walton S. Moody, Air Force History & Museums Press, 1996.

Seventy Years of Strategic Air Refueling, 1918–1988, Offutt Air Force Base, 1990.

The Development of Strategic Air Command 1946–1986, J.C. Hopkins and Sheldon A. Goldberg, Offutt Air Force Base, 1986.

USAF 50th Poster. An illustrator specializing in transport and technical military subjects, John Batchelor has produced thousands of color artworks, line drawings, and cutaways over the last 30 years.

Jan Adkins, a former art director at *National Geographic*, has written over 30 books and is now finishing up an illustrated history of bridges for young people.

John Sotham is an associate editor at *Air & Space/Smithsonian*.

20,000-Hour Tuneup. Washington D.C.-based writer Carl Hoffman is a frequent contributor to *Air & Space*. He wrote "Gary and the Pirates" (Feb./Mar. 1997).

Cameron Davidson's goal is to photograph all 50 states from the back seat of a JetRanger in a 60-degree left bank.

Erik Hildebrandt photographed the Grumman OV-1 surveillance aircraft for "Last of the Mohawks," which appeared in the Feb./Mar. 1997 issue.

Hover Dance. Frequent contributor Frank Kuznik last wrote "Spacesuit Saga: A Story in Many Parts" (Aug./Sept. 1997).

Further reading: *Dancing Rotors: A History of U.S. Military Helicopter Precision Flight Demonstration Teams*, Harry E. (Ned) Gilliand Jr., Aerofax, 1994.

Welcome to the Club. Carl Posey is finishing his sixth novel, *Red Man's Will*, in which aviation, astronomy, copper, and Nazis converge in Vienna, the American southwest, and Chile.

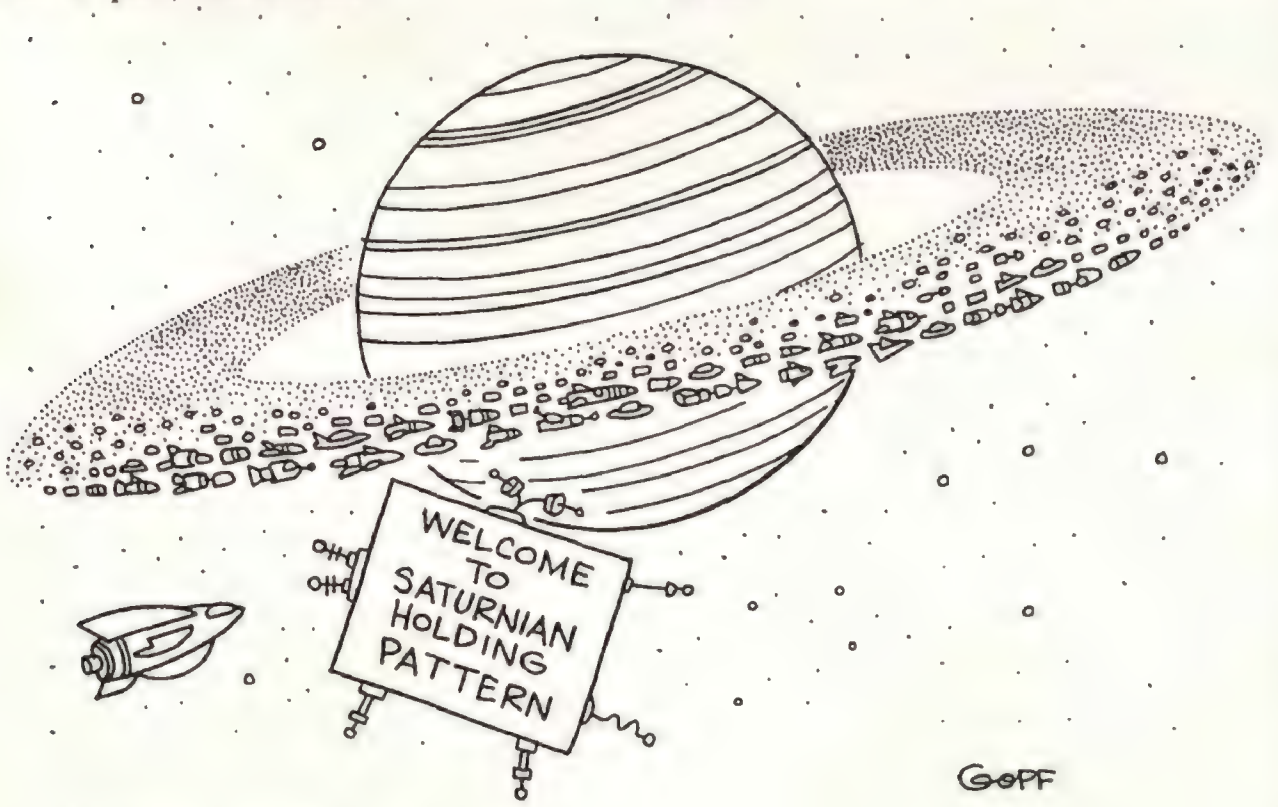
David Peters, an aviation buff and collector of 20th century pop culture kitsch, teaches digital illustration at Otis College of Art and Design in Los Angeles.

Watson's Whizzers. Phil Scott is a freelance writer living in New York City. A private pilot, he has logged a grand total of 3.1 hours in U.S. fighter jets.

Further reading: *War Prizes*, Phil Butler, Midland Counties Publications, 1994.

Fields and Streams. Tony Reichhardt is a consulting editor of *Air & Space*.

Rocket Man. Frequent contributor Richard Sassaman is based in Bar Harbor, Maine.



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ALL-NEW SPACEBEAT

The space shuttle carries into orbit plenty of stuff that never makes the news. Check out SpaceBeat before every launch to learn about secondary payloads and scientific experiments. (www.airspacemag.com/ASM/Web/Spacebeat.html)

FORECAST

In the Wings...

Secret Airlift to Tibet
In 1959, as China crushed Tibet, the CIA's air force flew covert missions over the Himalayas by the light of the full moon.

Incoming!
On a tiny island in the South Pacific, a crew of U.S. Army technicians occupies ground zero for test launches of ICBMs.

Other Oceans
We're learning that water is everywhere in the solar system. Does that mean life is as well?

A Week in the Life of NASA's Dryden Center
What's flying at the world's most famous flight research facility?

Sun in a Bottle
Astrophysicists no longer need to look to other galaxies to understand exploding stars. They've found a key right in the laboratory.

Monster Engines
In 1946 Lycoming built the X-7755, which was the size of a small room. For engineers, it was the golden age of propulsion.

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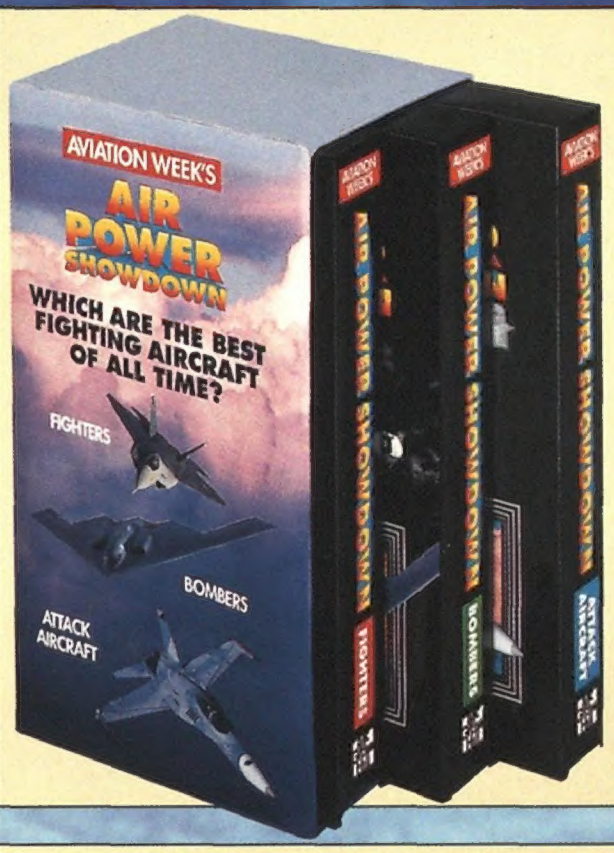

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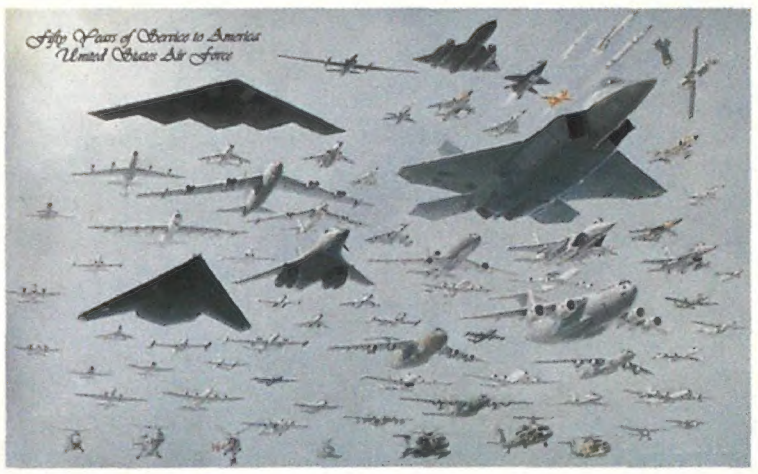

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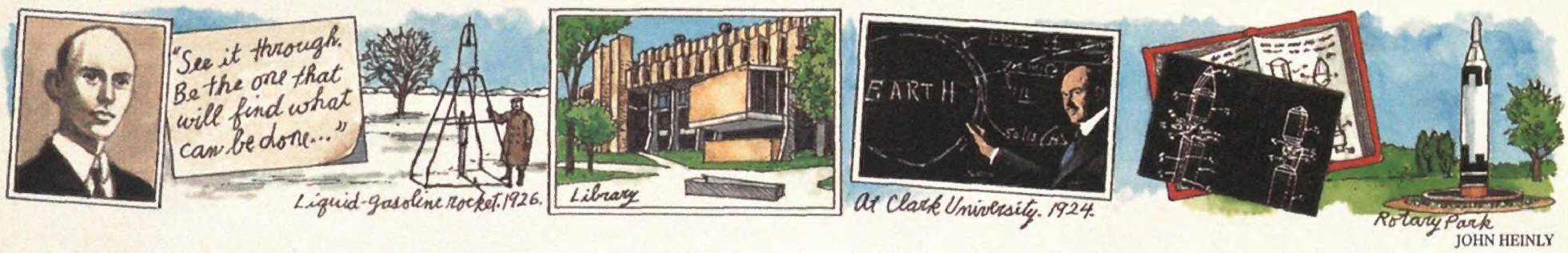

JOHN HEINLY

Rocket Man

American space travel, you could argue, began on October 19, 1899, in a cherry tree in Worcester, Massachusetts. A 17-year-old named Robert Goddard had climbed the tree to prune it, and before returning to earth he had a vision. "I imagined how wonderful it would be to make some device which had the possibility of ascending to Mars," he later wrote. "I was a different boy when I descended the tree...."

Goddard spent his life trying to perfect such a "device," which ultimately led to the development of the modern rocket. Today, his work is commemorated in the Goddard Exhibition Room, located in the library of Worcester's Clark University, where Goddard also taught physics for 29 years.

The inventor had his first success at 2:30 p.m. on March 16, 1926, at his Aunt Effie's farm in nearby Auburn. Using a blowtorch to ignite the propellants, he launched a 10-pound missile 41 feet into the air. Less than three seconds later, the world's first liquid-fuel rocket landed in a cabbage patch.

Goddard graduated to more powerful rockets. His fourth launch, conducted on July 17, 1929, was so loud it brought out two ambulances, the police, and a search airplane, all looking for a big wreck. "Terrific Explosion as Prof. Goddard of Clark Shoots His 'Moon Rocket,' " read the headline in the *Worcester Evening Post*. The Massachusetts fire marshal banned the inventor from further rocket testing in the state.

Goddard went out west in search of wide-open spaces. In the 1930s and early '40s, he worked out of Eden Valley, New Mexico, conducting both flight and static firing tests. Those experiments gave him enough data to fill 25 volumes with detailed notes. The books are now part of Clark University's Goddard collection, along with the inventor's diaries, 15 notebooks he kept on his theories, and 3,600 feet of motion picture film. A variety of artifacts flesh out the collection: a little cast iron tank Goddard used in 1920 for his first experiments with liquid fuel, a combustion chamber and nozzle he tested in 1937, a telescope he used to track the rockets that he launched in New Mexico, 18 of his oil paintings, and an unusual model airplane with both a rocket engine and a propeller, which he tested successfully at Clark in 1930.

Each year about 3,000 people, ranging from documentary filmmakers to school children doing reports, visit the collection. Major space accomplishments always arouse interest, as do anniversaries of Goddard's first rocket launch, says Dorothy Mosakowski, coordinator of the university's library archives and special collections.

The Robert Hutchings Goddard Exhibition, Clark University, 950 Main Street, Worcester, MA 01610; phone (508) 793-7572. Hours: 10 a.m.–4 p.m. Open Mon.–Fri., Sept.–May; Tues.–Thurs., June–Aug. Admission free.

A number of well-known people pictured on the walls of the exhibit room have visited too. Wernher von Braun, who chaired a committee to raise money for the library, declared that two of Goddard's 214 patents are "the essence of all rocketry, and the blueprint for our exploration of outer space." And astronaut Buzz Aldrin, whose father attended Clark, presented Goddard's wife with the first book taken to the moon: a miniature edition of her husband's autobiography. The book now resides in the collection.

Despite all his accomplishments, Goddard attracted "public criticism, misunderstanding, and even ridicule" throughout his life, according to one museum display. "My mother Virginia grew up half a mile from the university—on Thayer Street, just uphill from Goddard's house," says Tim Boulay of Clark University's media office. "She remembered him as a nice man, although the neighbors used to call him 'Loony Moony.' "

Today, though, the region is respectful of its most famous inventor. The local Rotary Club maintains a Robert Goddard memorial park behind the Auburn fire station, and Clark University has built a Goddard Memorial Plaza, with a stainless steel and granite sculpture symbolizing the parabolic curve of a rocket's flight path. And not far down Highway 12 there's Rocketland, a children's playground with a spaceflight theme.

One person who always believed in Goddard was his wife Esther, whom he met in 1920. At the time, he was almost 40 and she was 17, a secretary to Clark's president. Four years later, when she had turned 21 and his appointment as head of the university physics department earned her parents' approval, they were finally married.

Goddard died in 1945, and Esther donated his papers to Clark. After the exhibition room was set up in 1969, she would pass time there drinking coffee and reminiscing. "She was a lovely lady and worked very hard in his behalf," says Mosakowski.

Esther Goddard said that she became a "rocket buff" at the first test flight she ever attended. "Once you see it, you're hooked," she told one writer, who noted that she had served as a "mender of parachutes, field photographer, and stamper-out of fires at Aunt Effie's [farm]." She took the now-famous photograph of Goddard standing beside his rocket stand just before his first launch, and even had a movie camera along. (Unfortunately, it held only seven seconds of film, which ran out before the rocket was fired.)

As keeper of the Goddard flame, Esther spent the spring and summer of 1954 typing out more than 17,000 diary entries her husband had made over 47 years. Looking at this typescript, which is now at the Goddard collection, we see that on October 16, 1899, Goddard "looked off with telescope & climbed apple tree and ate apples."

Three days later, he had a more interesting time in the cherry tree.

—Richard Sassaman

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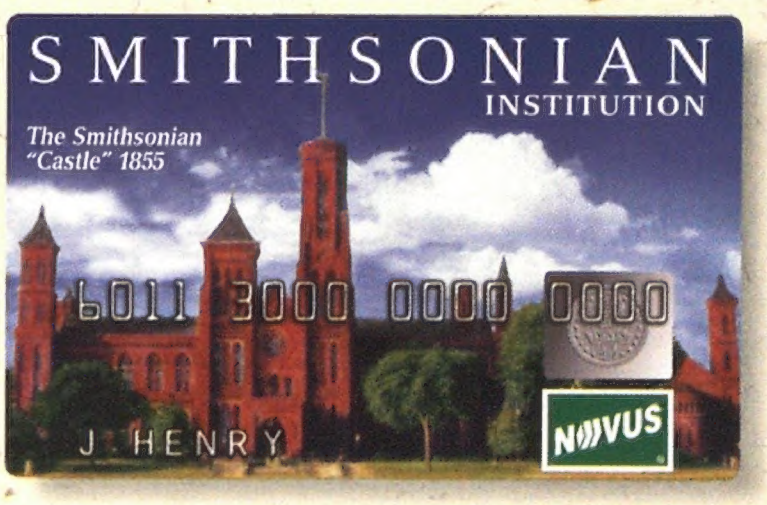

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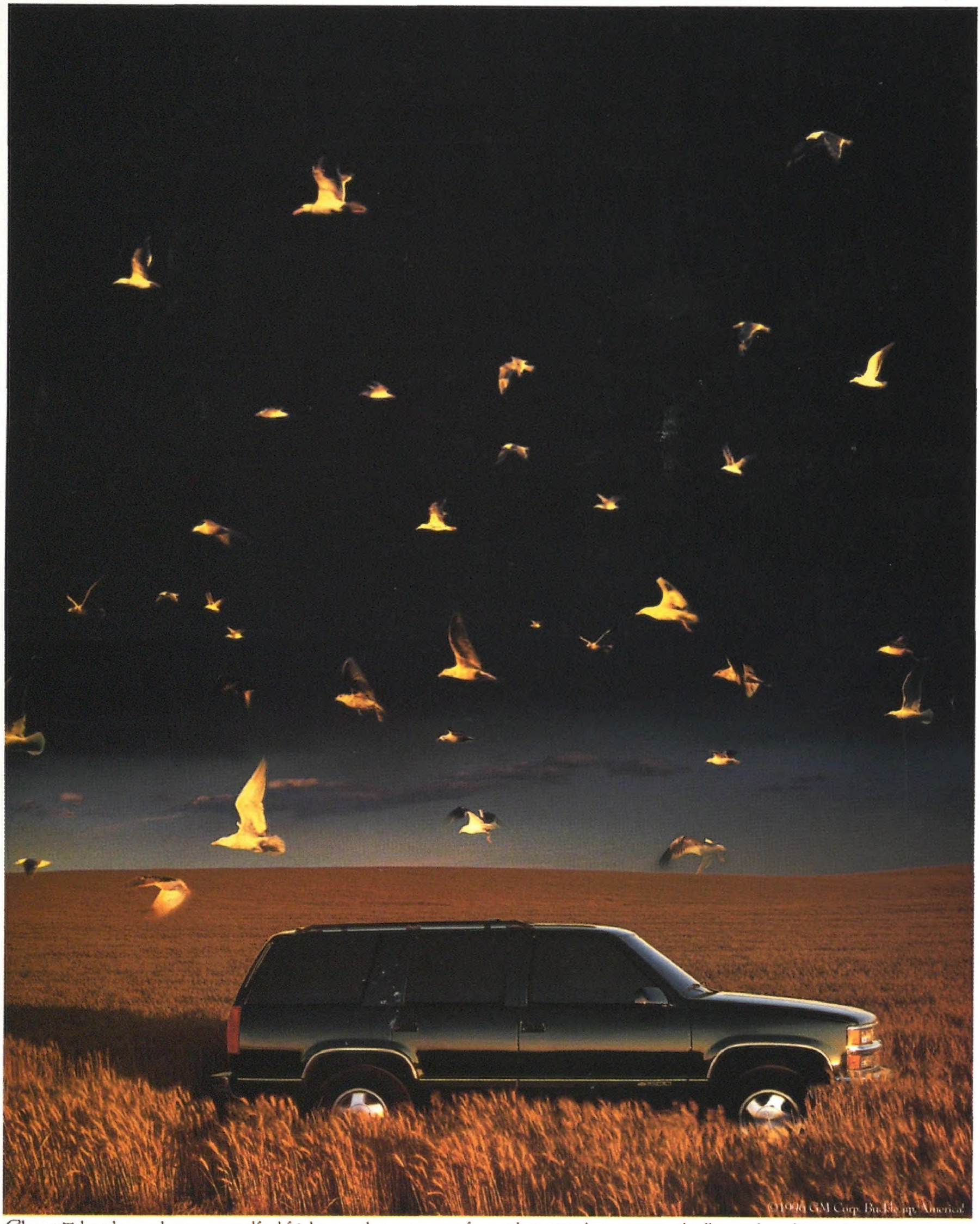
I FIND THE GREAT THING IN THIS WORLD
IS NOT SO MUCH WHERE WE STAND, AS IN WHAT DIRECTION WE ARE MOVING. -Oliver Wendell Holmes, Jr.



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